



United States Department of Agriculture

SPRING MOUNTAINS NATIONAL RECREATION AREA

MID-LEVEL EXISTING VEGETATION CLASSIFICATION AND MAPPING

HUMBOLDT-TOIYABE
NATIONAL FOREST



Forest
Service

Intermountain
Region

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Executive Summary

Existing vegetation classification, mapping, and quantitative inventory (VCMQ) products for the Spring Mountains National Recreation Area (SMNRA) were developed to help the Humboldt-Toiyabe National Forest better understand the spatial distributions of vegetation types, structural classes, and canopy cover. These products were developed collaboratively with the SMNRA, the Remote Sensing Applications Center (RSAC), the Intermountain Regional Office (RO), and the Interior West Forest Inventory and Analysis (IWFIA) program. The final maps align with the Existing Vegetation Classification, Mapping, and Inventory Technical Guide (Nelson et al. in press). The vegetation maps comprise 20 vegetation types, seven canopy cover classes, and six tree size classes for forest and woodland types. An accuracy assessment was completed to help users quantify the reliability of the map products and support management decisions that use this information. The existing vegetation products discussed in this document will help users to better understand the extent and distribution of vegetation characteristics for mid-level planning purposes, and disclose the methods and accuracies of these products. The SMNRA mid-level existing vegetation project is one among many VCMQ projects currently being completed in the Intermountain Region.

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Introduction

Existing vegetation classification, inventory, and mapping was completed on over 300,000 acres of the Spring Mountains National Recreation Area (SMNRA) in southern Nevada to standards established by the Intermountain Region Vegetation Classification, Mapping, and Quantitative Inventory (VCMQ) team and outlined in the Existing Vegetation Classification, Mapping, and Inventory Technical Guide (Nelson et al. in press). The purpose of the project was to provide up-to-date and more complete information about vegetative communities, structure, and patterns across the SMNRA landscape. Fulfilling this purpose is important in measuring compliance with National Forest Management Act (NFMA) obligations such as providing for a diversity of vegetation and associated habitat for terrestrial wildlife species.

Some resource management applications of the existing vegetation products may include ecosystem and wildlife habitat assessments, rangeland and watershed assessments, fuel load assessments, benchmark analysis, range allotment management plan updates, threatened and endangered species modeling, and recreation management.

This document provides an overview of the methods, products, and results of classification, inventory, mapping, and accuracy assessment activities that have been completed for the SMNRA. Other districts of the Humboldt-Toiyabe National Forest were previously mapped by the Pacific Southwest Region Remote Sensing Lab (Bridgeport and Carson Districts) and by the Intermountain Region in partnership with the Remote Sensing Applications Center (Austin, Ely, Jarbidge, Mountain City, Ruby Mountains, Santa Rosa, and Tonopah Districts).

Region 4 VCMQ Objectives

The Intermountain Region (Region 4) has identified the development of vegetation map products and associated inventory and classification work as one of its highest priorities since 2008. The goal of this effort has been to facilitate sustaining or restoring the integrity, biodiversity, and productivity of ecosystems within the Region by providing a sound ecological understanding of plant communities, their composition and structure. Specific goals are to:

- i. Help our forests continue to manage the lands according to their land management plans
- ii. Provide the public with an initial classification, inventory and map of mid-level existing vegetation in the Intermountain Region

- iii. Establish a baseline of landscape ecological conditions, including vegetation type, tree size, and canopy cover distributions and locations throughout the Region
- iv. Establish consistent methodologies and standardized data that meet best available science requirements, eliminate redundancies, leverage consistency, save money, and establish a framework for future activities
- v. Develop scientifically credible products that meet business requirements at multiple scales and for multiple purposes
- vi. Develop an update and maintenance program to ensure decisions are made based on the best available information

Intended Uses

The products discussed in this document can be used to address a variety of important land management issues related to watersheds, forest characteristics, rangelands, fuel loads and wildlife habitat. The products are also critical in supporting the Comprehensive Inventory and Monitoring Strategy for Conserving Biological Resources of the Spring Mountains National Recreation Area (METI 2008). Feasible applications include resource and ecosystem assessments, species habitat modeling, benchmark analysis, design of monitoring procedures, and a variety of other natural resource analysis applications. Specifically for the SMNRA, the products will be useful for planning large-scale fuel reduction projects, landscape-level post-fire restoration projects, quantifying wild horse and burro habitat, providing information to the public, and managing endemic species habitat throughout the mountain range. These products may provide information for targeting areas requiring investigation for potential projects or determining where more detailed studies are needed. Additionally, data collected during this effort may feed into broader-level analyses, such as determining estimates of nation-wide biomass, analyzing climate change responses, or mapping land cover.

Business Needs Requirements

The development of existing vegetation classification, inventory and map products is at the heart of our Agency's mission (<http://www.fs.fed.us/fsjobs/forestservice/mission.html>), "Our mission, as set forth by law, is to achieve quality land management under the sustainable multiple-use management concept to meet the diverse needs of people." One mission activity that is directly related to the development of vegetation products is identified as "developing

and providing scientific and technical knowledge aimed at improving our capability to protect, manage, and use forests and rangelands.”

More recent Forest Service initiatives strengthen the need for acquiring existing vegetation information for our Forests and Grasslands. The National Forest System Land Management Planning Rule (36 CFR Part 219) Subpart A—National Forest System Land was published in the Federal Register on April 9, 2012, and became effective 30 days following the publication date. The new planning rule establishes “ecological sustainability” as a primary objective in forest management, and addresses “conservation of water flow and assurance of a continuous supply of timber as set out in the Organic Act, and the five objectives listed in the Multiple-Use Sustained Yield Act of 1960 (Public Law 86-517): outdoor recreation, range, timber, watershed, and wildlife and fish.”

Included in the new planning rule regulations, the plan monitoring program addresses the applicability of eight requirements per 36 CFR 219.12(a) (5). The SMNRA’s existing vegetation effort addresses three of the eight plan monitoring program requirements: 1) the status of select watershed conditions, 2) the status of select ecological conditions including key characteristics of terrestrial and aquatic ecosystems, and 3) the status of a select set of the ecological conditions required under §219.9 to contribute to the recovery of federally listed threatened and endangered species, conserve proposed and candidate species, and maintain a viable population of each species of conservation concern.

The 2012 planning rule also requires the responsible official to use the “best available scientific information” (BASI) to inform the assessment, the development of the plan (including plan components), and the monitoring program. It requires that responsible officials document how the best available scientific information was used.

More recently, the Forest Service has developed a draft strategy for inventory, monitoring, and assessment (IM&A) activities as directed in the Forest Service Manual (FSM-1940). The strategy establishes a comprehensive approach for conducting IM&A activities in the agency that responds to our priority business requirements. Of particular note, the draft IM&A strategy lists existing vegetation as a sidebar for the strategy, and includes the statement “Existing vegetation, for example, is the primary natural resource managed by the Forest Service and is the resource on which the agency spends the most money for inventories and assessments” (USDA Forest Service 2013).

The SMNRA existing vegetation mapping project attempts to meet the requirements, policy, and guidelines for properly managing our Forests through standardized protocol development and implementation, data standardization, reliable data processing, defensible methodologies, and full disclosure. These policy, guidelines and requirements establish the collection of existing

vegetation information and mapping products as a requisite to proper land management in the area.

General Characteristics of the Area

The Intermountain Region of the Forest Service encompasses nearly 34 million acres of the National Forest System. This region contains 12 Forests in the states of Idaho, Utah, Nevada, Wyoming, Colorado, and California where four major geographic provinces come together (Great Basin, Colorado Plateau, Northern Rocky Mountains, and Middle Rocky Mountains). This geographic diversity is one reason for the Region's variety of ecosystems and landscapes. The Intermountain Regional Office in Ogden, Utah, provides administrative support for the Region's National Forests and Grasslands.

Administered as a U.S. National Recreation Area by the Humboldt-Toiyabe National Forest, the SMNRA spans approximately 316,000 acres, located about 20 miles west of downtown Las Vegas, Nevada (**Figure 1**). The Spring Mountains rise from a low-lying desert (2,000 feet), forming an 'island' of mountainous terrain capped by Mt. Charleston (11,918 feet.). This elevation gradient yields a wide variety of vegetation zones, ascending from arid shrublands (Mojave and blackbrush), to woodlands (pinyon-juniper, gambel oak, mountain mahogany) and montane shrublands (manzanita, currants, ceanothus), coniferous forests (white-fir, ponderosa pine, limber pine, bristlecone pine), to alpine communities (common juniper and many endemic forbs) at the highest elevations. Hot and dry climatic conditions in low-lying valleys have isolated many species on the range, resulting in a richness of endemic flora and fauna.

Limestone and dolomite are the primary parent materials of the soils on the SMNRA. Most of the soils belong to Aridisols, Mollisols, or Entisols. The precipitation regime is characterized as bimodal; the majority of precipitation falls during two seasons as either snow during the winter or rain during monsoonal events in the summer. The mountain receives approximately 8–24 inches of precipitation per year depending on elevation (J. Hurja, personal communication, January 23, 2015). Additionally, over 220 springs and seeps are located across the range.

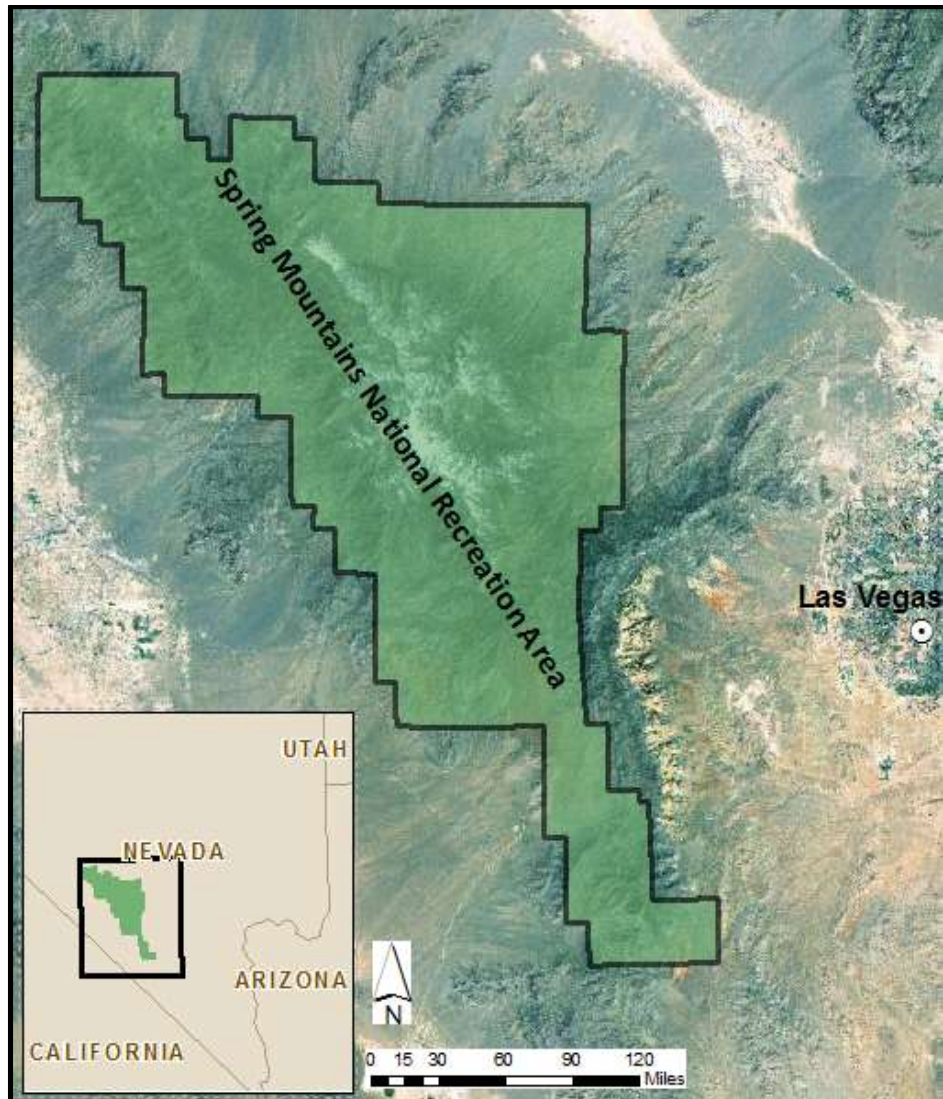


Figure 1: The SMNRA is located approximately 20 miles west of downtown Las Vegas, Nevada.

Introduction to Methods

Maps depicting existing vegetation types, canopy cover and tree size class were developed using moderate and high resolution imagery, topographic data, ancillary GIS layers, field and photo-interpreted reference data, automated image segmentation, and data-mining classification techniques.

The remotely sensed imagery assembled for this project included moderate and high resolution satellite and aerial imagery. Four Landsat scenes (30-meter spatial resolution) were assembled depicting spring, summer, and fall conditions. The high resolution imagery included 2013

WorldView-2 satellite data (1.8-meter), and 2006 and 2010 National Agricultural Imagery Program (NAIP) aerial photography (1-meter). U.S Geological Survey Digital Elevation Models (DEM) (10-meter) were compiled. Other ancillary GIS layers that were gathered include climate, geology, wildfire severity, soils, and interferometric synthetic aperture radar (IfSAR) data¹.

The WorldView-2 imagery was resampled to 10 meters for modeling purposes. Vegetation indices and image transformations were generated from the Landsat and WorldView-2 satellite data and topographic information was derived from the digital elevation models². All imagery and topographic derived information were projected to a common geographic coordinate system (UTM, NAD83, Zone 11 N). Modeling units (image segments) were developed using resampled WorldView-2 imagery, Landsat data, and topographic derivatives.

Field sites were collected in homogenous modeling units during the summer of 2013 and information on composition, canopy cover, and tree size was recorded. Additional reference information was obtained from previously collected field data and photo interpretation methods.

Map unit labels (vegetation type, canopy cover class, and tree size class) were assigned to the modeling units using Random Forests (Breiman 2001). Random Forests is a method of automated computer classification and regression that uses reference and geospatial data to develop decision trees. Each map (vegetation type, canopy cover class, and tree size class) was developed individually using distinct reference data sets and geospatial data layers.

Draft maps were distributed to local resource specialists for review and final revisions were made based on the feedback. Maps were completed by aggregating and filtering the modeling units to the minimum map feature size. Aspen, rock outcrop shrubland, alpine, and barren/sparse vegetation types were filtered to 2 acre minimum polygon size, the riparian vegetation type was filtered to a 1 acre minimum polygon size, while all other vegetation types were filtered to 5 acres minimum polygon size. An accuracy assessment was conducted and descriptions of the vegetation type map units were written.

¹ See [Appendix I: Acquired Geospatial Data for Mapping](#).

² See [Appendix II: Vegetation Indices, Transformations, and Topographic Derivatives](#).

Results Summary

The final map products depict continuous land cover information for the entire project area including the SMNRA and private land inholdings. Maps are formatted as a geodatabase, which is compatible with Forest Service corporate GIS software. The vegetation maps are consistent with mid-level mapping standards set forth in the Existing Vegetation Classification, Mapping, and Inventory Technical Guide (Nelson et al. in press). In conformance with these standards, modeling units were aggregated up to 5 acres, with the exception of aspen, rock outcrop shrubland, alpine, and barren/sparse vegetation types; these were aggregated to two acres and the riparian vegetation type which were aggregated to one acre. Additional products include field-collected reference information and photographs, seasonal Landsat image mosaics and derived vegetation indices, topographic derivatives, climate data, surface information derived from IfSAR, fire history, and burn severity information.

Although the 2013 Carpenter 1 Fire occurred during the same year as the mapping project, the final map products depict pre-fire conditions. This was due to the timing of project initiation in early 2013 and the acquisition of satellite imagery and collection of field reference data prior to the fire's occurrence. Consequently, the map information may be useful in providing baseline information to inform post-fire assessment and restoration planning.

Partnerships

The mid-level existing vegetation products were collaboratively planned, developed, and implemented by technicians and experts within the Forest Service. These partnerships were critical to ensuring the highest level of integrity, objectivity, and usefulness for internal uses such as landscape assessments, and for external consumption by the public. The primary participants in the development included SMNRA and Regional Office staffs, the Remote Sensing Applications Center (RSAC) and the Interior West Forest Inventory and Analysis (IWFIA) Program of the Rocky Mountain Research Station (**Figure 2**).

The Intermountain Regional Office established the VCMQ core team in 2009 to create existing vegetation products for regional and forest-level uses, such as forest-planning-level analysis, broad-scale analysis, monitoring, and assessments, and as a framework for project-level analysis. The team provides expertise in botany and ecology, silviculture, forestry, remote sensing, inventory and mapping, GIS, and program management.

The SMNRA is a primary stake holder in the derived outcomes of this project since they administer the lands and use these products for land management activities. The SMNRA has collaborated on all aspects of the vegetation mapping project from the initial needs assessment to the final accuracy assessment. A focused group of forest resource specialists, contract specialists, and GIS specialists helped identify tasks and deliverables, made recommendations based on user needs, and served as Forest representatives to the collaborative effort. A broader audience of resource specialists and program managers reviewed draft map products, provided field-based knowledge, and offered suggestions to make the deliverables more meaningful from a Forest perspective.

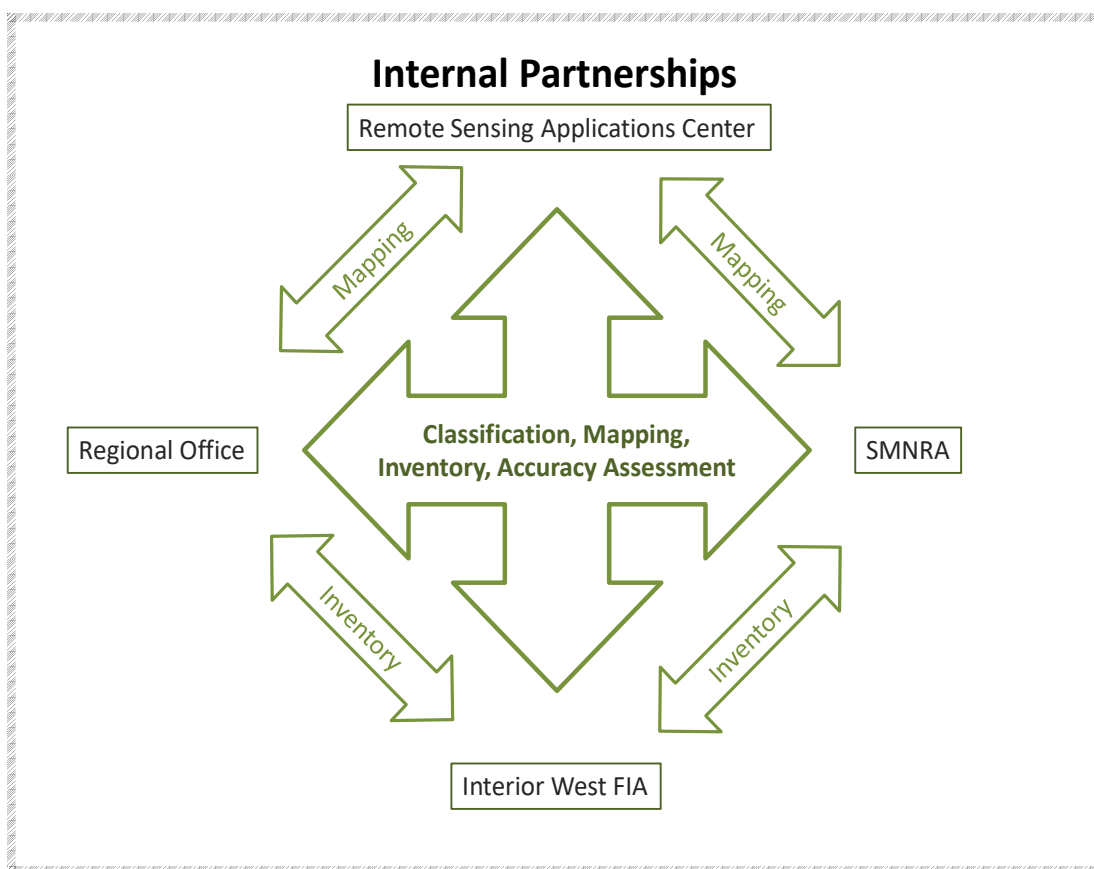


Figure 2: Partnerships developed for the classification, mapping, inventory, and accuracy assessment conducted on the SMNRA.

RSAC is a national technical service center of the USDA Forest Service. The mission of RSAC is to provide the Forest Service with the knowledge, tools, and technical services required to use remote sensing data to meet the agency's stewardship responsibilities. RSAC's Mapping,

Inventory and Monitoring program provides operational remote sensing support and analysis services to help meet internal and interagency programmatic assessment and monitoring needs, such as this existing vegetation mapping project. RSAC is the principal provider of remote sensing technical expertise and map production techniques for this effort. The center has assisted in this effort in all aspects: data collection, remote sensing analyses, image segmentation, image analysis, field reference data protocol and sample design, map filtering, map production, draft map reviews, and final report development.

The IWFIA unit operates under technical guidance from the Office of the Deputy Chief for Research and Development, located in Washington, DC, and under administrative guidance from the Director of the Rocky Mountain Research Station located in Fort Collins, Colorado. This research unit provides ongoing support for the inventory aspects of the project: FIA inventory on forest land and all-condition inventory (ACI) on nonforest plots, contract inspections, data collections, database assistance, pre-field inspections, intensified inventory sample design, and accuracy assessment. Their participation ensures consistency and establishes credible and defensible inventory data to be used in conjunction with the derived map products.

Methods

The phases for this project included project planning, data acquisition and processing, classification development, segmentation, map unit legend design, reference data collection, modeling, draft map review and revision, and final map development (**Figure 3**). After the final maps are completed, an accuracy assessment, vegetation type map unit description, and dominant type descriptions are developed.

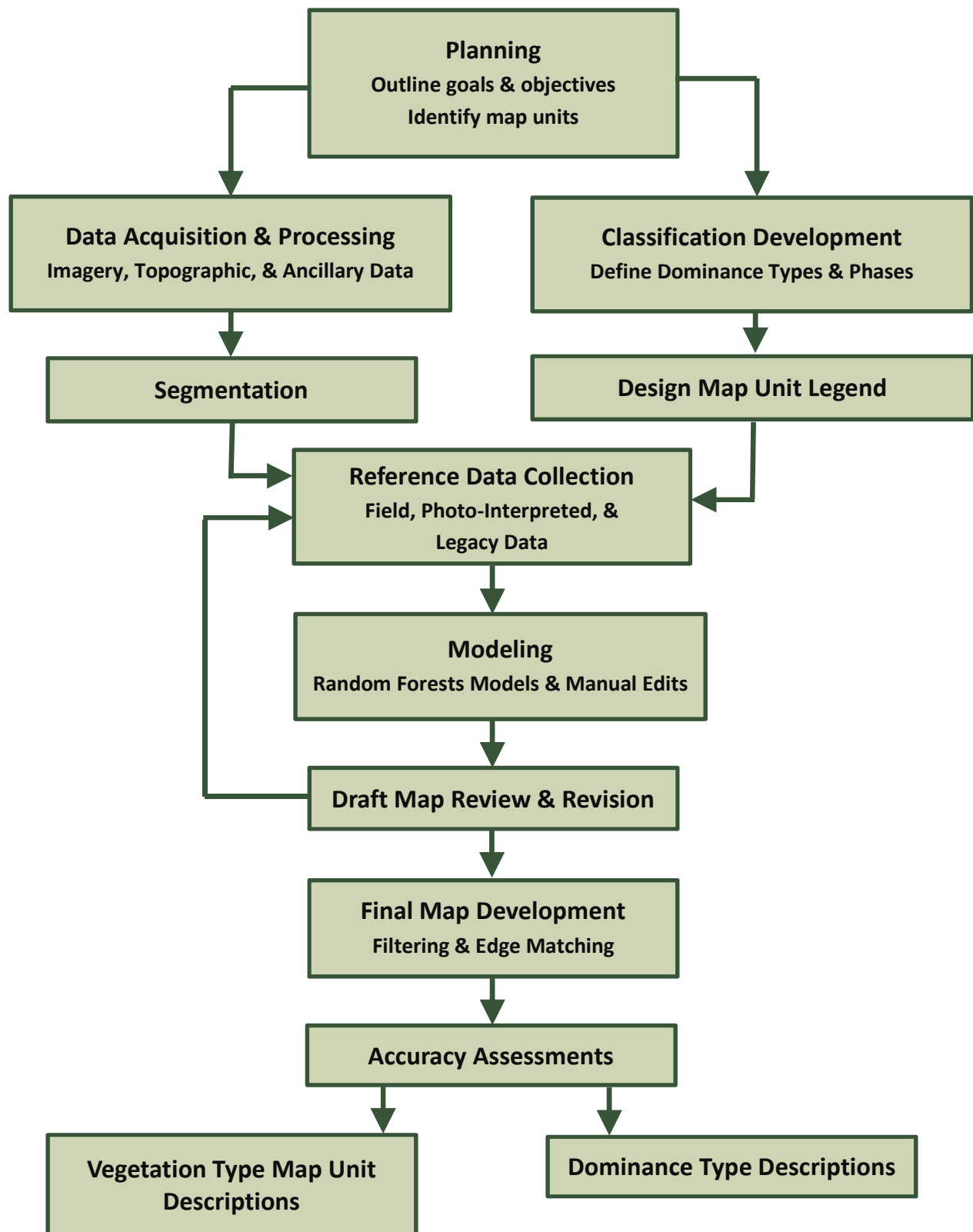


Figure 3: Project phases from project planning to descriptions of vegetation type map units and dominance types.

Project Planning

In 2013, staff of the SMNRA, Intermountain Regional Office, and RSAC met to discuss map unit design and prepare a project plan. Since one of the goals for the project was to provide a regionally cohesive map product, efforts were made to ensure that processes and spatial and thematic characteristics of the maps would fulfill regional requirements. A classification of dominance types and phases was developed to address forest information needs. These were combined into vegetation types that achieved a balance between map detail and accuracy within the allocated budget and time constraints. The final vegetation type map units conformed to the mid-level mapping standards referenced in the Existing Vegetation Classification, Mapping, and Inventory Technical Guide (Nelson et al. in press), while the canopy cover, and tree size map units were selected to represent the management needs of the Forest and recreation area.

Vegetation Classification Development

The Intermountain Region's VCMQ program is designed to classify, map, and quantitatively inventory existing vegetation across the Region. At the regional level, existing plant communities are assigned to dominance types based on the most abundant species of the ecologically dominant life form (e.g., the most abundant tree species in forests or woodlands). This approach was decided upon by a council with representatives from each Forest in the Region.

At the Forest level, the regional dominance types may be subdivided into dominance type phases based on associated species of the same life form as the dominant species. Forests are able to define these phases to best meet their own information needs, as long as they nest within the regional dominance types.

An initial list of dominance types is compiled using Forest vegetation plot data and vegetation classification literature relevant to the Forest. The list is reviewed and augmented by Forest resource specialists and local contributors. The Forest specialists determine whether any dominance types need to be split into phases and how those should be defined. Rules for distinguishing phases are tested using the regional plot database and a taxonomic key to dominance types and phases is developed. In practice, phases have only been defined in forests and woodlands, not in shrublands or herblands.

Vegetation Type Map Units

Once the classification is developed, Forest and Regional specialists develop a map legend by determining which dominance types and phases should be mapped individually, and identifying which dominance types and phases can be combined. Overall map accuracy decreases as the number of map units increases; therefore, the team seeks to balance map detail versus map quality. This process is informed by applying the Forest dominance type key to FIA plot data and estimating the acreage of each type on the Forest. The initial map legend is complete when each dominance type and phase has been assigned to a map unit and included in the dominance type key.

SMNRA Process

The above Regional process was followed to develop the dominance type classification and vegetation type map legend for the SMNRA (Tart et al. 2015)³.

Plot data used to compile a list of dominance types and test definitions of phases included data collected for classification of community types (Manning and Padgett 1995; Nachlinger et al. 1996; West et al. 1998; Charlet and Leary 2013) and LandFire reference data. Plot data collected for the Spring Mountains Terrestrial Ecological Unit Inventory (unpublished) were also used.

Other relevant vegetation classification literature used in developing the Spring Mountains dominance type classification included Mueggler (1988), Youngblood (1985), Charlet and Leary (2012), and Charlet et al. (2012).

Structural Characteristics

Structural technical groups for tree size and tree and shrub canopy cover were identified by Humboldt-Toiyabe National Forest and SMNRA resource specialists to meet business information requirements specified in the land and resource management plans (Forest Plans). Tree size and canopy cover technical groups were established to represent a diversity of vegetation structure and density classes appropriate for informing the management and maintenance of physical and biological processes. The identified classes facilitate the

³ See [Appendix III: Existing Vegetation Keys](#).

assessment and monitoring of forest and nonforest (rangeland) vegetation, ecological patterns and processes, and wildlife habitat. In identifying structure and density map classes, considerations were also made related to the feasibility of mapping the identified categories using mid-level remote sensing mapping techniques.

Tree Size Class

Tree size class or tree diameter class is any interval into which a range of tree diameters may be divided for classification (Helms 1998). Tree size is represented by the plurality of a given class forming the uppermost canopy layer as viewed from above. Tree size classes for forest (**Table 1**) and woodlands (

Table 2) differ in individual diameter class breaks and in the representation of methods used for measurement. Forest species are measured using diameter at breast height (DBH) (4.5 feet above the ground) and designated woodland species (**Table 3**) are measured using diameter at root collar (DRC). Specific procedures used for measuring DRC are found in the Field Reference Data Collection Guide⁴.

Table 1: Forest tree size map classes represented by diameter at breast height (DBH)

Forest Tree Size DBH Class (in)	Code
0 – 8.9	F-TS1
9 – 20.9	F-TS2
≥ 21	F-TS3

Table 2: Woodland tree size map classes represented by diameter at root collar (DRC)

Woodland Tree Size DRC Class (in)	Code
0 – 11.9	W-TS1
12 – 17.9	W-TS2
≥ 18	W-TS3

⁴ See [Appendix IV: Field Reference Data Collection Guide and Protocols](#).

Table 3: Designated woodland species measured by diameter at root collar (DRC)

Symbol	Scientific Name	Common Name
JUOS	<i>Juniperus osteosperma</i>	Utah juniper
JUSC2	<i>Juniperus scopulorum</i>	Rocky Mountain juniper
PIMO	<i>Pinus monophylla</i>	singleleaf pinyon
CELE3	<i>Cercocarpus ledifolius</i>	curlleaf mountain mahogany
QUGA	<i>Quercus gambelii</i>	Gambel oak

Tree and Shrub Canopy Cover Class

Canopy cover from above represents the total non-overlapping canopy in a delineated area as viewed from above (Nelson et al. in press). Overlapping canopy not visible from above is not assessed or counted. Four tree and three shrub canopy cover percent classes representing total cover were created on the SMNRA (**Table 4** and **Table 5**).

Table 4: Map classes for total tree canopy cover as viewed from above.

Tree Canopy Cover Percent Class	Code
10 - 20	TC1
21 - 40	TC2
41 - 70	TC3
≥ 71	TC4

Table 5: Map classes for total shrub canopy cover as viewed from above.

Shrub Canopy Cover Percent Class	Code
10 - 20	SC1
21 - 30	SC2
≥ 31	SC3

Data Acquisition

Geospatial Data

Geospatial data acquisition is a major activity in most vegetation mapping efforts that use digital image processing methods. This activity involved assembling remotely sensed images of various spatial and spectral resolutions and an array of geospatial data⁵. A requirement of the mapping process was that any data layer used must be available across the entire SMNRA to ensure consistency. Data used included imagery from the National Agriculture Imagery Program (NAIP) and WorldView-2, topographic data in the form of Digital Elevation Models (DEMs), burn severity information from the Monitoring Trends in Burn Severity (MTBS) program, surface climate conditions data generated by the Daily Surface Weather and Climatological summaries (Daymet), interferometric synthetic aperture radar (IfSAR) data, and four orthorectified Landsat 5 Thematic Mapper satellite images from 2010, and one Landsat 8 OLI (Operational Land Imager) from 2013. In addition, enterprise data such as USFS administrative boundaries, land ownership, roads, trails, hydrology, harvest activities, geology, and soils resource inventory data were provided by the SMNRA.

Vegetation Plot Data and Photo Interpretation

Vegetation plot data were assembled and aerial photo interpretation was conducted to obtain a reference data set representative of the map units (vegetation type, canopy cover, and tree size class) depicted on the final maps. Reference data are intended to represent a statistically robust sample of broader vegetation conditions across the entire study area. They are used both as training data in model development and to assist with image interpretation. For this project, three types of reference data were used: legacy vegetation plot data, newly collected field reference data, and photo-interpreted data.

Legacy Vegetation Plot Data

Pre-existing plot data from several sources were compiled to develop a list of dominance types on the SMNRA and test criteria for phases. Multiple data sources and associated plot

⁵See [Appendix I: Acquired Geospatial Data for Mapping](#).

information were used for developing dominance type classifications and reference data for vegetation mapping (**Table 6**).

Additionally, 230 FIA and intensified plots comprising 244 conditions were available from both annual and “periodic” datasets. These were used in developing the dominance type and the map legend, but were not used as reference data for the mapping process. They were used to assess the overall accuracy of the map and to describe the composition of the final vegetation type map units.

Table 6: Data sources and associated plots used for developing dominance type classifications and reference data for vegetation mapping on the SMNRA.

Data Set	Dominance Type Classification Plots	Map Reference Plots
Community Type Plots		
Manning and Padgett 1995	15	15
Charlet et al. 2013	---	360
Nachlinger and Reese 1996	337	353
West et al. 1998	7	7
TEUI/Soil Survey Plots		
Spring Mountains TEUI	192	192
LandFire Reference Plots		
LandFire	---	155
Totals	551	1,082

Newly Collected Field Reference Data

New field reference data were collected in 2013 to capture the variation of vegetation composition communities and structure classes across the project area. Data were collected at field-selected plot locations by RSAC personnel. Information gathered included dominant plant species composition, tree and shrub canopy cover, and forest and woodland tree diameter. Dominance type and corresponding vegetation type map unit were determined according to

the existing vegetation keys⁶. Percent canopy cover and associated map units were identified using ocular estimation and line intercept methods.

Photo Interpretation

All of the new field reference data acquired in 2013 were photo-interpreted to validate segment homogeneity and representativeness of the field calls for vegetation type and structure classes. In addition, for field-visited sites, tree canopy cover as viewed from above was estimated across the full extent of the segment for attaining an interpreted cover class assignment representative of the segment modeling unit.

Image and Geospatial Data Processing

Project Area Buffer

For modeling purposes only, the SMNRA administrative boundary was buffered by 0.25 mile to account for edge effects that can occur along the clipped edge of some topographic and image data sources that may negatively impact the classification models. The buffered area was not included in the final map deliverables. Private lands completely contained within SMNRA were included in the project area to maintain spatial contiguity and are part of the final map deliverables. However, no reference data was gathered within these areas or lands outside the Forest boundary.

All geospatial data, including ancillary GIS layers, remotely sensed images, and topographic layers, were projected to the UTM Zone 11, GRS 1980, NAD83 coordinate system and clipped to the buffered project area.

LANDSAT Imagery

All Landsat imagery was co-registered and obstructions (e.g., haze, clouds, cloud shadows) were removed and replaced to develop three seamless seasonal mosaics: spring, summer, and fall. A regression technique was used to replace clouds and cloud shadows and create seamless

⁶See [Appendix III: Existing Vegetation Keys](#).

mosaics between neighboring Landsat scenes. Model II regression is a statistical technique that uses a common area between two images (i.e., overlap between adjacent Landsat scenes) to develop a regression model for each of the spectral bands on the image. The regression equation is then used to “fit” the target image to the reference image by adjusting the pixel values in the non-overlap areas to facilitate the creation of a seamless mosaic between images. Two spectral transformations (Tasseled Cap and Principal Component Analysis) and one spectral index (Normalized Difference Vegetation Index (NDVI)) were produced from the final Landsat mosaics. These derivatives are useful in discriminating between vegetated and non-vegetated as well as between vegetation cover-types.

High Resolution Imagery

The 1.8-meter WorldView-2 imagery was resampled to 10 meters and mosaicked. This step increased the processing efficiency of image segmentation by reducing the resulting segment file size while still maintaining image resolution appropriate for mid-level mapping. An NDVI and Principal Component Analysis transformations were produced using the visible and near infrared bands.

Digital Elevation Models (DEMs) and Topographic Derivatives

Topographic derivatives including three slope-based products (slope, slope-aspect (cos), and slope-aspect (sin)), were developed from the 10-meter DEM (Ruefenacht 2014), as well as slope position, aspect, surface to ground ratio, heatload, and hillshade. Such topographic models are used in the modeling process to depict environmental parameters that help predict vegetation cover types.

IfSAR Data

Interferometric synthetic aperture radar (IfSAR) data estimates vegetation height by taking the difference between two radar returns with different wavelengths. One wavelength returns to the sensor after contact with the ground, and the other wavelength returns to the sensor after coming in contact with vegetation. IfSAR difference products were used for the mapping of tree

size class, since it correlates with tree height. Unfortunately, IfSAR data is inconsistent across mountainous terrain where steep slopes prevent the radar data from being acquired. Consequently, vegetation height was modeled in areas where IfSAR data was inconsistent.

Other Data

In addition to the image and topographic layers, change detection metrics were developed using the Landsat data record. These layers characterized forest disturbance and/or recovery using automated change detection algorithms. Outputs from the Vegetation Change Tracker (VCT) were used to produce these metrics. Time series stacks spanning from 1984-2011 were used, which matched the period of the normalized burn ratio (NBR), NDVI, and a forest-z score (Huang et al. 2010). The five correlates of forest disturbance/recovery were disturbance, no change, recovery, rate of decline, and rate of recovery. These layers were especially useful in identifying regions affected by fire or harvest activity.

Segmentation

Image segmentation is the process of partitioning digital imagery into spatially cohesive polygonal segments (modeling units) that represent discrete areas or objects on a landscape (Ryherd and Woodcock 1996). The goal of developing segments is to simplify complex images comprised of millions of pixels into more meaningful and mappable objects. Excluding water bodies, the final segments (modeling units) ranged in size from 0.28 to 42 acres with an average size of approximately 3.6 acres.

Modeling units were produced using Trimble eCognition's multi-resolution segmentation algorithm (**Figure 4**). This algorithm is a bottom-up segmentation technique, whereby pixels are recursively merged together based on user-defined heterogeneity thresholds to form discrete image objects. The input data layers used to generate segments were resampled 10-meter WorldView-2 imagery (raw bands, NDVI, and principal components), Landsat imagery (principal components) and topographic data used as a proxy for riparian zones (slope-aspect transformation). There are four primary parameters within eCognition's multi-resolution segmentation algorithm that control the spatial and spectral quality of the resultant segments.

They are: layer weights, scale, shape, and compactness. Layer weights control the relative influence that each of the raster data layers have on the segmentation process⁷.

The majority of the influence was given to the spectral WorldView-2 data. While all layers contribute valuable information to the segmentation process, the “texture” of the higher-resolution, multi-spectral data is often most effective at distinguishing between distinct vegetation types and conditions.

Scale is a unit-less parameter that controls the amount of allowable heterogeneity within segments. Scale parameters can range from 1 to infinity, where the low end would delineate polygons only around identical pixels and the high end would result in the entire study area delineated as a single polygon. As such, scale can also be seen as a proxy control for segment size. A high scale parameter means more heterogeneity is allowed within segments and will ultimately result in larger relative segment sizes. Conversely, a small scale parameter means less heterogeneity is allowed within segments, so smaller segments will result. For the SMNRA segmentation, a scale parameter of 14 was used. The appropriate scale factor was determined by experimentation and previous experience with other forests.

⁷ See [Appendix V: eCognition Layer Weights](#).

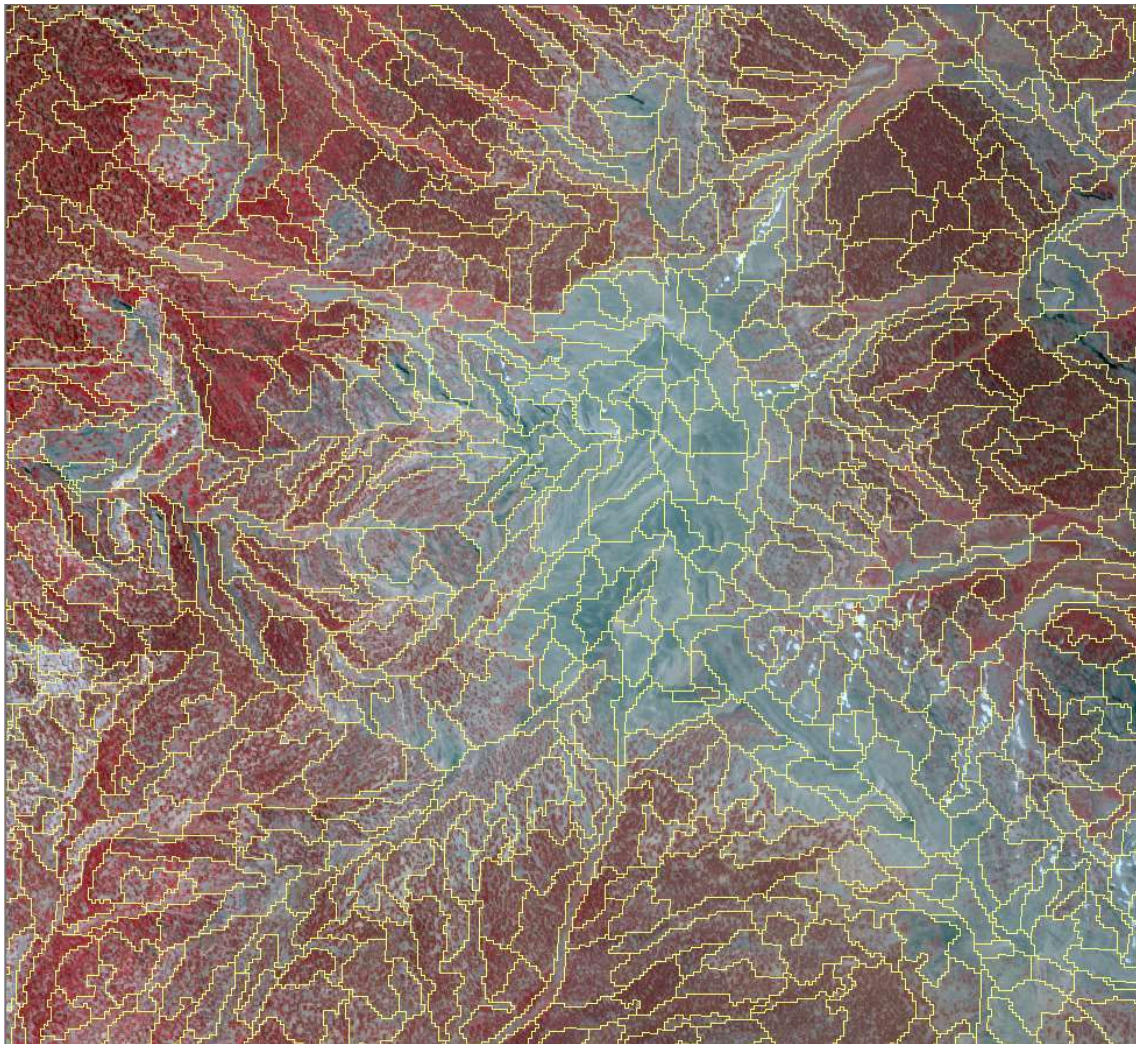


Figure 4: An example of modeling units generated using eCognition software overlaid on false color WorldView-2 imagery.

The shape parameter controls the type of heterogeneity contained within the resultant segments. It is a relative value that caters to the desire for resultant segments to be controlled by spatial homogeneity (shape) and/or spectral homogeneity (color). The values range from 0.0 (a low shape parameter/high color parameter) to 0.9 (a high shape parameter/low color parameter). Segments created with a low shape parameter will have very spectrally homogeneous segments, but less compactness or smoothness of the resultant segments. Conversely, a very high shape parameter will result in segments that have very smooth, compact shapes, but less variance of spectral and topographic pixel values. For the SMNRA segmentation, a shape parameter of 0.1 was used, which emphasizes spectral and topographic homogeneity over smoothness and compactness of segment shapes

Similar to the shape parameter, the compactness parameter actually weighs the balance between two opposing spatial qualities: compactness and smoothness. Compactness can be described as the ratio between the area of a given segment and the area of the smallest bounding box of that segment. A very compact segment (e.g., a circular or square segment) will have a ratio that approaches 1, while a segment with low compactness (e.g., an oblong or linear segment) will have a value that approaches 0. Smoothness can be described as the ratio between the length of a segment's boundary and its area. A very smooth segment will have a short border relative to its area, whereas an irregular segment will have a lengthy border relative to its area. The value of the compactness parameter ranges from 0.0 (low compactness/high smoothness) to 1.0 (high compactness/low smoothness). For the SMNRA segmentation, a compactness parameter of 0.5 was used, which equally balances the shape and compactness of segments.

In addition to the base parameters described above, RSAC has developed additional components to the segmentation rule set, including the definition of a minimum mapping unit (MMU) and associated MMU filtering techniques, and an "object smoothing" process that sends the raw segments through a majority filter-based re-shaping tool that results in smoother, more spatially consistent and functional modeling units.

Field Reference Data & Photo Interpretation

Field and photo interpretation data were collected to obtain a reference data set with a sufficient number of samples for modeling vegetation type, tree and shrub canopy cover class, and tree size class. This section describes the methods used for collecting new and legacy field data, and the photo interpretation procedures for obtaining tree canopy cover estimates and assessing reference site homogeneity and representativeness.

New Field Site Collection

During spring and summer of 2013, RSAC collected field data using handheld GPS displays with segments and imagery. This provided a field assessment of segment homogeneity and minimized data collection from non-suitable locations. Upon arriving at appropriate sites, RSAC field crews followed the established SMNRA vegetation key⁸ and reviewed the entire segment

⁸ See [Appendix III: Existing Vegetation Keys](#).

for vegetation type, canopy cover class, and tree size class. This assessment was done from an aerial perspective because the map represents an overhead view of the vegetation.

Ocular estimates of canopy cover for trees, shrubs, herbaceous and non-vegetated cover types were recorded for the plot, totaling 100 percent cover. Overlapping canopy not visible from above was not counted as part of the estimates. In addition to the ocular cover estimates, a transect intercept method was used at regular intervals for shrubland plots to calibrate ocular estimates. Two perpendicular 100-foot transects were run through the segment center. Within each 10-foot transect increment, the number of feet of live canopy cover intercepted for each species was estimated and totaled for each transect. The transect percentages were then averaged to calculate the overall shrub canopy cover. Based on the composition and cover estimates, a dominance type and corresponding vegetation group and vegetation type were assigned to the segment using the vegetation keys and map unit cross-walk.

For forest and woodland sites, the percent visible cover from above of each tree size class was estimated by species and then totaled for each size class. Tree size was determined using DBH for forest species while DRC was determined for woodland species (juniper, pinyon pine, gambel oak and curleaf mountain mahogany) (**Table 3**). The tree size class having the most abundant total canopy cover was used for assigning a tree size map unit.

Between field visits, an adaptive sampling strategy was taken in which the numbers of each vegetation type were tabulated and under-sampled communities were identified to target these communities during future field visits. In order to expedite sampling efforts, the majority of field reference data were collected within 0.25 mile of roadsides. Additional information regarding field sampling procedures is discussed in the Field Reference Data Collection Guide⁹.

Legacy Field Sites

Nearly 700 additional sites with vegetation type information were collected by Dr. David Charlet from the College of Southern Nevada in Henderson, Nevada. Dr. Charlet used the taxonomic key to assign vegetation types, and provided RSAC with GPS coordinates of the field locations. These data underwent a rigorous QA/QC process in which RSAC eliminated 216 data

⁹ See [Appendix IV: Field Reference Data Collection Guide and Protocols](#).

points that were deemed outdated/inaccurate or occurred in non-homogenous segments. A total of 482 plots from this data set were used as reference sites.

Photo Interpretation

Aerial photo interpretation was conducted by RSAC. An integrated approach combining field experience and field-sampled data was used to characterize vegetation composition and structure from digital high resolution resource aerial imagery. The photo interpretation process provided an efficient and cost-effective means to supplement and validate field-based data.

Tree Canopy Cover Estimates

In order to acquire more consistent and accurate reference data, approximately 1,200 segments were photo-interpreted for canopy cover. Segments were selected by generating a random sample of the forest and woodland areas identified on the draft vegetation type map. This allowed for improved sample size and data acquisition in inaccessible or remote locations. RSAC personnel, who were familiar with vegetation of the SMNRA, assigned a canopy cover amount for the entire segment. Canopy cover was interpreted by comparing cover within the segment to known canopy coverage scales and interpreted examples.

Homogeneity and Representativeness

Photo interpretation was also used to assess segment homogeneity and representativeness of field training reference sites. Homogeneity interpretations involved identifying whether each segment containing a field reference site represented a homogenous vegetation formation. The representativeness of the field training reference site was determined by identifying whether the field-assigned attribute for vegetation group, vegetation type, and tree size class (as applicable) reasonably represented the majority of the segment. Together with the photo interpretation for homogeneity of the segment, the representativeness interpretation allowed for assessing the suitability of each field site attribute for appropriate use as training reference data in the modeling process.

Modeling

Modeling was the step in the mapping process that developed the statistical relationships between the reference data and the geospatial data. These statistical relationships were then applied to building a map. Each model output was carefully evaluated. To improve the model results, reference data were reevaluated, changes or additions were made, and an updated

model was developed. This modeling procedure was repeated until the maps were considered satisfactory.

An important task in the modeling process was the development of draft maps to share with resource specialists. This step allowed resource specialists to take maps into the field for verification, apply local knowledge, and make suggestions for improvements to the map products. This feedback allowed modelers to make map changes and improvements prior to final map delivery.

Map Types

Vegetation Type Map

Vegetation types were mapped using a hierarchical approach. A mapping hierarchy determined the sequence in which models were run, and incorporated the vegetation types most difficult to separate (**Figure 5**). Broad life form types, such as tree and non-tree, were mapped first. These communities were subsequently divided into more distinct categories until the final vegetation types were mapped. There are several advantages to using this hierarchical approach. It enables a targeted review of maps at each level, where conspicuous errors can be addressed at the upper levels of the hierarchy, and it provides additional reference sites for mapping the broad classes.

The mapping hierarchy was developed using a data clustering technique based on the relative separability of each vegetation type. Separability was determined by how well the spectral and ancillary data could distinguish between vegetation types. It is quantified by a value known as “entropy,” which measures how well a model could be expected to separate vegetation types beyond random chance. Vegetation types with low entropy values are expected to be modeled poorly and vegetation types with high entropy values are expected to be modeled well. The mapping hierarchy was built from the bottom up, by identifying and aggregating the least separable classes first.

For each level of the mapping hierarchy, a Random Forests model (Breiman 2001) was developed, and the resulting output map was carefully evaluated. To correct inconsistencies, reference data were reevaluated, changes or additions were made, and an updated model was developed. This modeling procedure was repeated until the maps were considered satisfactory.

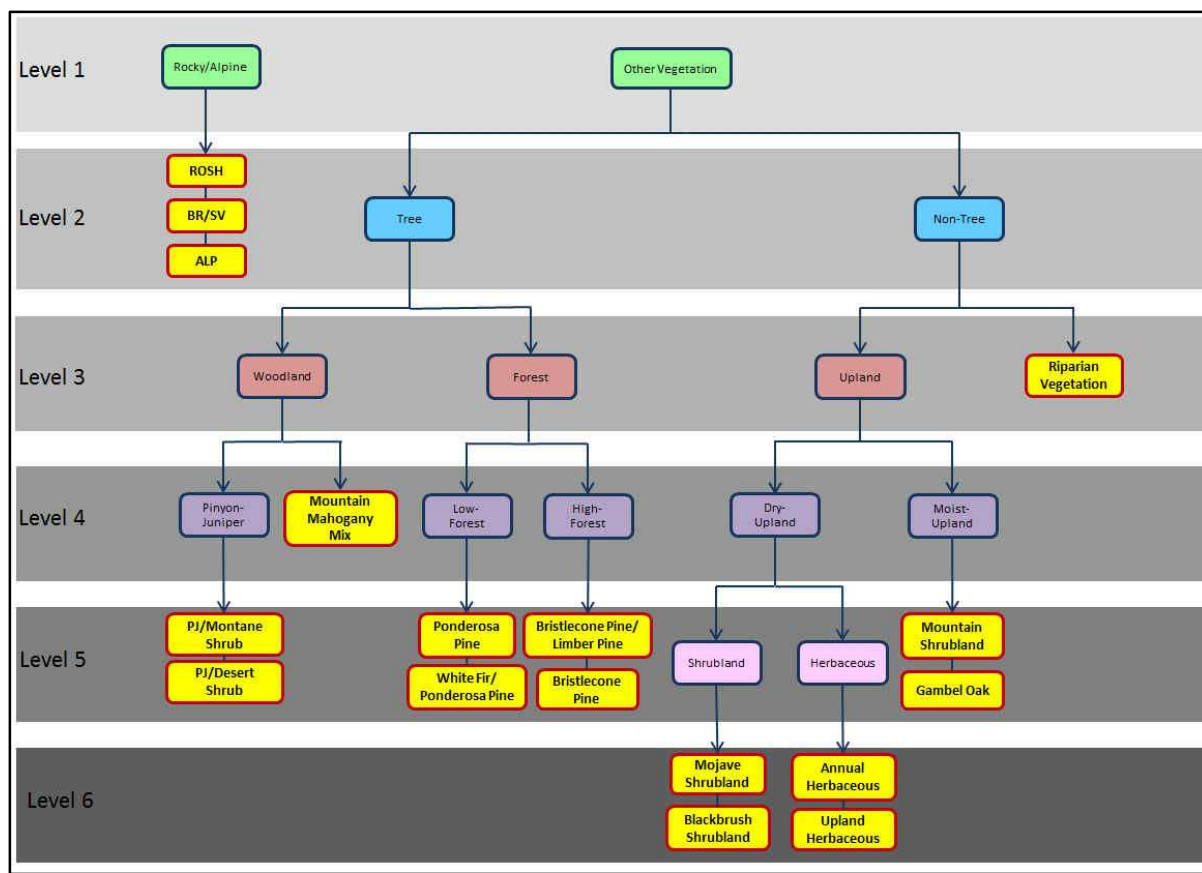


Figure 5: Mapping hierarchy example used in the modeling process for the vegetation type map. Successive models were developed starting with level 1 (broad separation of land cover) and progressing to higher levels (more refined). At each level a separate map was developed and reviewed for accuracy.

Canopy Cover Class Map

Canopy cover was assigned to forest, woodland, and shrubland modeling units identified on the vegetation type map. The canopy cover percentages for forest and woodland sites were photo-interpreted, while shrubland sites were assessed in the field.

To optimize modeling effectiveness, vegetation types were sorted into five canopy groups based on vegetation similarities (**Table 7**). Some groups contained multiple vegetation types while others contained a single type.

A Random Forests model was developed for each canopy group. The output was a continuous canopy cover map. These maps were evaluated using the high resolution imagery and additional reference sites were added if necessary. The continuous maps were assigned canopy

cover map units and the individual group maps were combined to produce the final canopy cover map.

Table 7: Canopy cover groups used for modeling canopy cover.

Canopy Cover Group	Vegetation Type
Aspen	Aspen
Conifer	Ponderosa Pine, White Fir/Ponderosa Pine, Bristlecone Pine/Limber Pine, Bristlecone Pine
Woodland	Pinyon-Juniper/Desert Shrub, Pinyon-Juniper/Montane Shrub, Mountain Mahogany Mix, Gambel Oak
Mountain Shrub	Mountain Shrubland, Rock Outcrop Shrubland, Riparian Vegetation
Desert Shrub	Mojave Shrubland, Blackbrush Shrubland

Tree Size Class Map

Tree size class was assigned to modeling units identified as forest or woodland vegetation types. These types were sorted into three groups based on the similarity of vegetation types and the tree size measurements (**Table 8**). Woodland types were measured using diameter at root collar while forest types were measured using diameter at breast height. Tree size was then modeled independently for each group. Time series analysis layers and derived Landsat imagery that characterizes forest disturbance and/or recovery were used in addition to the customary geospatial predictors¹⁰. The individual group maps were combined to produce the final tree size map.

¹⁰ See [Appendix VI: Tree Size Class Modeling Data Layers](#).

Table 8: Tree groups and the associated vegetation types used for tree size mapping.

Tree Size Groups	Vegetation Type
Aspen	Aspen
Conifer	Ponderosa Pine, White Fir/Ponderosa Pine, Bristlecone Pine/Limber Pine, Bristlecone Pine
Woodland	Pinyon-Juniper/Desert Shrub, Pinyon-Juniper/Montane Shrub, Mountain Mahogany Mix, Gambel Oak

Draft Map Review and Revision

The vegetation type draft map was provided to local forest resource specialists for comment and review. Meetings were held in Las Vegas, NV where the review process and associated materials were presented to the Forest staff and other parties¹¹. Both digital (Webmap services) and hardcopy products were offered. This was an opportunity for local experts to assess the map and give additional information to make improvements.

All the draft map review comments were compiled and reviewed by the vegetation mapping team and the recommended changes were used to produce the final vegetation type map.

Final Map Development

Three final map products were produced for delivery: 1) vegetation type; 2) canopy cover class for trees and shrubs; and 3) tree size class. For the vegetation type map, segments were first dissolved to merge adjacent polygons of the same type. To achieve the minimum map unit (MMU) of 5 acres, with the exception of aspen, rock outcrop shrubland, alpine, and barren/sparsely vegetated types (2 acres), and riparian vegetation (1 acre), segments below the MMU were merged based on a set of rules developed by the Regional Office and SMNRA staff¹². The rules followed logic based on similarities between adjacent polygons, so that neighbors were merged with the most similar type of vegetation. An example of this dissolving and filtering process is shown in **Figure 6**. For the canopy cover and tree size maps, segments were dissolved and merged using a similar process. For example, the first choice for filtering out a small TS1 map feature was to merge it with a neighboring TS2 map feature, since that is the most similar class.

¹¹ See [Appendix VII: Draft Map Review](#).

¹² See [Appendix VIII: Merge Rules for Segments Less Than MMU Size](#).

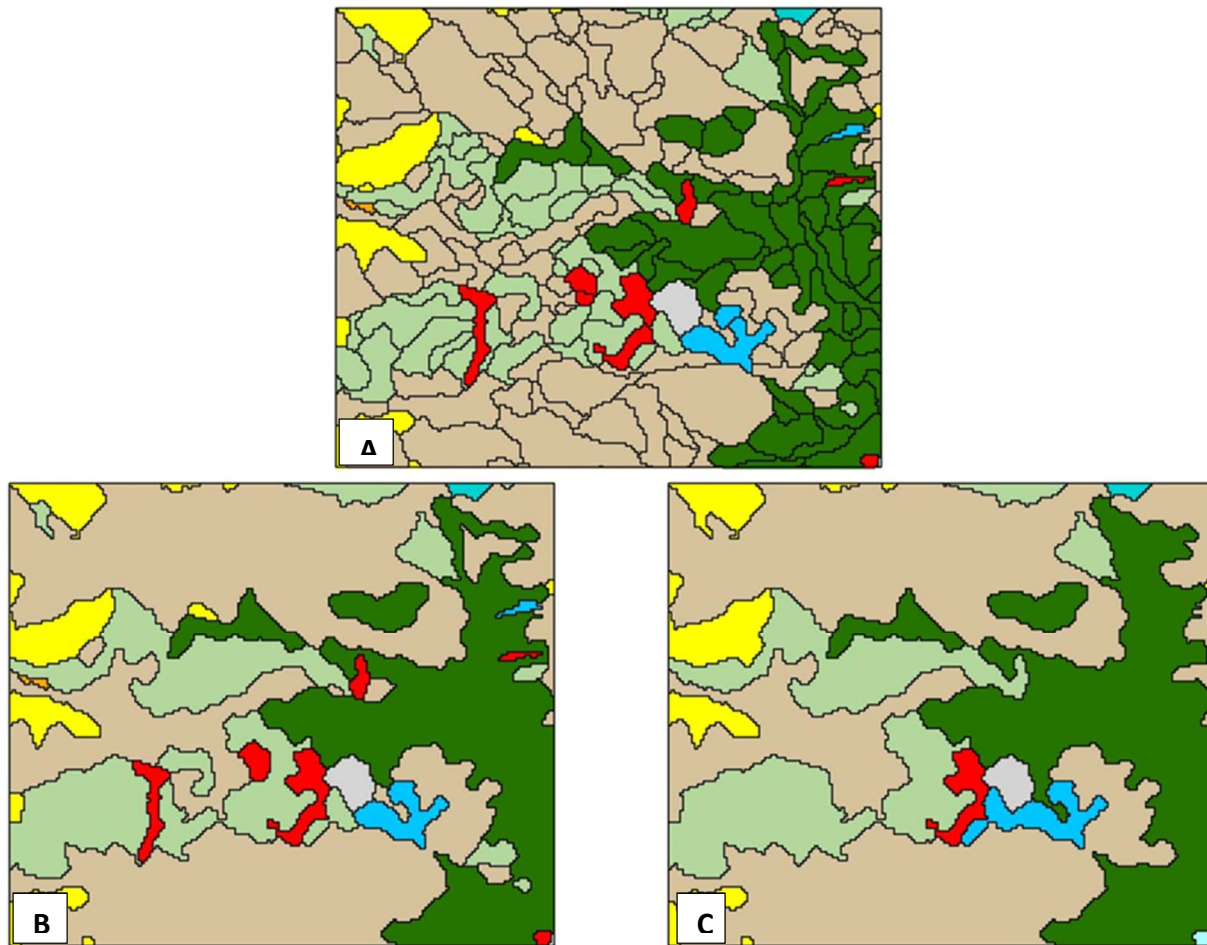


Figure 6: An example of the dissolving/merging and filtering process that was performed on the final maps. Image A shows the original vegetation type map with no dissolving or filtering. Image B illustrates the dissolving and merging of adjacent map features labeled with the same vegetation type. Image C illustrates the filtering process. Segments smaller than the designated minimum map unit size were merged with similar adjacent map features based on the filtering rule-set.

Map Products

The final map products provide for continuous land cover, vegetation type, tree size, and canopy cover information for the entire SMNRA. The final maps were formatted as a digital geodatabase, which is compatible with Forest Service corporate GIS software. Categories included: Vegetation Group and Vegetation Type, Canopy Cover Class, and Tree Size Class. The vegetation map is consistent with mid-level mapping standards set forth in the Existing Vegetation Classification, Mapping, and Inventory Technical Guide (Nelson et al. in press). These minimum map feature standards were also maintained in the canopy cover and size class maps.

Vegetation Type and Group

A total of 20 vegetation types comprising seven generalized groups were mapped (**Table 9**). These classes ranged from specific vegetation species (e.g., Bristlecone Pine) to vegetation communities (e.g., Mojave Shrubland) and more general land use types (e.g., Developed).

Table 9: Total acres and percent area of Vegetation Types by Vegetation Group. Only National Forest System lands were included in the acre calculations.

Vegetation Type	Area (ac)	Percent area
Deciduous Forest		
Aspen	698	0.2
Conifer Forest		
Ponderosa Pine	1,743	0.5
White Fir/Ponderosa Pine	24,707	7.8
Bristlecone Pine/Limber Pine	6,860	2.2
Bristlecone Pine	9,057	2.9
Woodland		
Pinyon-Juniper/Desert Shrub	50,349	15.9
Pinyon-Juniper/Montane Shrub	95,704	30.2
Mountain Mahogany Mix	10,723	3.4
Gambel Oak	6,496	2.0
Shrubland		
Mojave Shrubland	5,167	1.6
Blackbrush Shrubland	76,034	24.0
Rock Outcrop Shrubland	2,118	0.7
Mountain Shrubland	19,243	6.1
Herbland		
Alpine Vegetation	370	0.1
Annual Herbaceous	3,672	1.2
Upland Herbaceous	2,890	0.9
Riparian		
Riparian Vegetation	206	0.1
Non-Vegetated/Sparse Vegetation		
Barren/Sparse Vegetation	732	0.2
Developed	100	0.0
Water	3	0.0
Total	316,871	100.0

Tree and Shrub Canopy Cover

A canopy cover map was generated by independently processing forest, woodland and shrubland canopy cover (**Table 10**). All other areas were mapped as having no canopy cover. Canopy cover categories were assembled into a wall-to-wall map for the entire SMNRA.

Table 10: Total acres and percent area for each tree and shrub canopy cover class. Only National Forest System lands were included in the acre calculations.

Tree canopy class	Area (ac)	Percent Area
TC1 (10 - 20%)	86,383	41.9
TC2 (21 - 40%)	101,702	49.3
TC3 (41 - 70%)	17,379	8.4
TC4 (71%+)	751	0.4
Total	206,215	100.0

Shrub canopy class	Area (ac)	Percent Area
SC1 (10 - 20%)	20,289	19.8
SC2 (21 - 30%)	50,959	49.6
SC3 (31%+)	31,477	30.6
Total	102,725	100.0

Tree Size

A tree size map was generated for all areas identified as forest or woodland in the existing vegetation map. These lands were classified into one of six tree size classes (**Table 11**). All other areas were mapped as having no size class. The tree size class map was assembled into a complete coverage for each mapping region and mosaicked for the entire SMNRA.

Table 11: Total acres and percent area for each tree size class. Only National Forest System lands were included in the acre calculations.

Tree Size Class	Area (ac)	Percent Area
FTS1 (0 - 8.9" DBH)	3,840	1.9
FTS2 (9 - 20.9" DBH)	24,041	11.7
FTS3 (21"+ DBH)	15,164	7.4
WTS1 (0 - 11.9" DRC)	42,435	20.6
WTS2 (12 - 17.9" DRC)	52,293	25.4
WTS3 (18"+ DRC)	68,441	33.2
Total	206,215	100.0

Accuracy Assessment

An accuracy assessment for a mapped product can be defined as a statistical summary or metric, usually presented as a table, comparing the mapped classes to reference data or “truth.” An accuracy assessment should provide objective information on the quality or reliability of the map, and can be used to determine the utility of the map and the associated risks of the map with respect to specific applications” (Nelson et al. in press). Thus, it is paramount that the reference information used to conduct accuracy assessments be independent from the information used to produce the map, and also be a reliable and unbiased source for representation of ground conditions.

Quantitative inventory data were used for this accuracy assessment. This included the most current Forest Inventory and Analysis (FIA) base-level, field-collected data available, consisting of a spatially complete systematic hex-grid sample for all forest and nonforest lands. Additionally, a set of intensified inventory plot data collected on the SMRNA by Interior West Forest Inventory and Analysis (IWFIA) were also used.

The source data set for this analysis was approximately nine years (2004-2012). Systematic inventory plots provide a spatially balanced estimate of map unit (e.g., vegetation type, canopy cover class, and tree size class) proportions for a population. Below are more detailed discussions concerning: 1) the use of reference datasets for accuracy assessments, 2) the use of the map product from the accuracy assessment perspective, and 3) the accuracy assessment design.

Use of Reference Datasets for Accuracy Assessments

Reference data is quantitative or qualitative information about ground features necessary to successfully complete a map accuracy assessment. Although the collection of field reference data is not required, some type of reference data is needed to help interpret and/or assess accuracy during a mapping project. Quantitative accuracy assessments usually depend on the collection of reference data, which is assumed to be known information of high accuracy (Brewer et al. 2005).

There is rarely a sufficient sample size to quantify all vegetation types occurring across a geographic area. Important types of naturally small extent, such as riparian communities, are

rarely sampled by a systematic or random design. Inventory data, therefore, involves trade-offs between resolution and reliability. It is often necessary to generalize or aggregate vegetation types and/or structural classes in order to achieve the sample sizes needed to provide statistically reliable estimates of the amounts of those types or classes (Brewer et al. 2005).

When data collection protocols for accuracy assessment samples are similar to those of the training samples, then assigning the appropriate map unit label to an accuracy assessment sample is straightforward. If plot designs are dissimilar, then developing a crosswalk and reinterpreting or verifying plot information using high-resolution imagery, or conducting field visits may be necessary. When existing data, such as FIA data, is used to assess map accuracy, consideration should be given to address differences in data collection methods (Stehman and Czaplewski 1998). The following are some limitations that need to be considered when using FIA or other data not explicitly designed for accuracy assessments:

- Size of FIA plot vs. unit of evaluation for the map
- Nature of FIA condition boundaries vs. mapped polygon boundaries
- Vintage of field collected data of annual cycle versus imagery vintage
- Insufficient numbers of accuracy assessment sites for less common classes

Although the use of FIA data as a reference dataset for accuracy assessments has its limitations, it also has many advantages. FIA data are a statistically robust, spatially distributed, unbiased sample that is updated annually over a 10-year cycle. It has well-established and consistent data collection protocols that facilitate multi-temporal comparability and long-term usage, and is readily available to users.

FIA data can be used early in the classification scoping process to identify or distinguish rare (< 1 percent of Forest), uncommon (1 to 10 percent), and common (>10 percent) classes. Rare classes are typically too spatially-limited for normal mid-level mapping processes, and may need to be “burned in” (incorporated) later using local Forest knowledge. This process can help make the mapping process more efficient, by reducing the number of initial classes and the number of classes that may need further collapsing after accuracy assessment completions based on too few samples.

For the less common classes, other sources of reference information are often needed (e.g., intensified, stratified or photo-interpreted data).

Use of Map Products

Map features (e.g., polygons) are rarely pure; instead, they usually contain varying proportions of vegetation, structure, and cover class mixtures. Therefore, map products should be used within the context of the map unit and the associated dominance type descriptions.

The map assessment may identify map units with low accuracy. These map units may meet the desired thematic detail, but not the desired thematic accuracy. By assessing the error structure relative to the mapping objectives and management questions, map units can be combined into new, more generalized map units that better meet accuracy requirements. Merging map units is not an edit or a correction to the final map; rather, this process is a generalization of the map legend to achieve an acceptable compromise between thematic detail and classification accuracy (Nelson et al. in press).

Accuracy Assessment Design

The three basic components of an accuracy assessment are the sample design, the response design, and the analysis protocol (Stehman and Czaplewski 1998). The sample design determines the plot design, and the distribution of sites across the landscape; the response design determines how the sites are labeled or assigned to map units; the analysis protocol summarizes the results of information obtained from the sampling and response designs.

Sample design and sample size (number of samples) are important considerations for an efficient accuracy assessment. The *sample design* should be statistically and scientifically valid. The sampling unit (i.e., polygon or point) should be identified early in the process, since it affects much of the plot design. While training data used for producing a map may be collected according to a preferential or representative sampling scheme (purposive sampling), data used for accuracy assessment should be collected using an unbiased approach, where samples have a known probability of selection (Stehman and Czaplewski 1998). The number of sample sites should be large enough to be statistically sound but not larger than necessary for the sake of efficiency. The need for statistical validity is often balanced with practical considerations, such as time and budget constraints (Nelson et al. in press).

The *response design* includes procedures for collecting the accuracy assessment samples, and protocols for assigning a map unit label to each accuracy assessment sample (Stehman and Czaplewski 1998). If an existing data set is used, determine whether the existing information is

sufficient for assigning a map unit label, or if additional information or interpretations are needed.

The *analysis protocol* summarizes the results of information obtained from the sampling and response designs (Stehman and Czaplewski 1998). A primary objective of an accuracy assessment is to quantify the level of agreement between mapped and observed attributes. This is most often performed for classified (categorical) maps by creating an error matrix, and deriving the accuracies from that matrix. The error matrix is the standard way of presenting results of an accuracy assessment (Story and Congalton 1986). This matrix is a cross-tabulation table (array) that shows the number of reference sites found in every combination of reference data category and map unit category. Agreement can also be measured by comparing the similarity of the mapped and observed proportions of the attributes within the mapped area.

Quantitative Inventory

Quantitative vegetation inventory consists of applying an objective set of sampling methods to quantify the amount, composition, condition, and/or productivity of vegetation within specified limits of statistical precision. To be most useful, a quantitative inventory must have a statistically valid sample design, use unbiased sampling methods, and provide both population and reliability estimates (Brewer et al. 2005).

Phase 2 FIA Base-level Inventory

The FIA program of the USDA Forest Service has been in continuous operation since 1930. Their mission is to conduct and continuously update a comprehensive inventory and analysis of the present and prospective conditions of the renewable resources of the forests and rangelands of the United States. This national program consists of five regional FIA units. The Interior West FIA unit, part of the Rocky Mountain Research Station, conducts inventories throughout National Forest System Regions 1-4.

Forest Lands

Although FIA's mission includes rangeland assessments, it is only funded to conduct forest land inventories. The Phase 2 forest inventory consists of permanently established field plots distributed across each state, with a sample intensity of about one plot per 6,000 acres. Field data are collected only on plots where forest land is present. In general, forest land has at least 10 percent canopy cover of live tally tree species of any size or has had at least 10 percent

canopy cover of live tally species in the past; based on the presence of stumps, snags, or other evidence. Each plot consists of a cluster of four subplots that fall within a 144-foot radius circle based on the plot center spread out over approximately 1.5 acres. Most phase 2 data are related to the tree and understory vegetation components of the forest. Plots are distributed on all ownerships across the country and thus will have the number of plots in proportion to the extent of a vegetation type on the landscape. For more details on national FIA please see <http://www.fia.fs.fed.us/> or on the FS web at <http://fsweb.ogden.rmrs.fs.fed.us/>.

All Condition Inventory

As the Intermountain Region (Region 4) has entered into an agreement with IWFIA to conduct a base-level, quantitative inventory or “All Condition Inventory (ACI)”, which collects similar vegetation information on both forest and nonforest lands throughout the region. The ACI is a joint effort initiated by FIA and the Northern Region (Region 1), and adapted for Region 4 needs. As an extension of the grid-based forest land inventories that FIA conducts on all ownerships throughout the Interior West states, the ACI will result in a consistent and unbiased wall-to-wall inventory on all Region 4 National Forest System (NFS) forest and nonforest lands. Nonforest includes all lands not considered forest land. Thus, the Northern and Intermountain Regions have collaborated with FIA to conduct a seamless inventory with the same data collection protocols on all NFS lands regardless of the presence or absence of tree cover.

Intensified Inventories

If Forest information needs justify further intensification, the FIA base grid can be supplemented with a set of intensified plots, as was the case on the SMNRA through a partnership with IWFIA. In 2010, the SMNRA requested IWFIA to increase the sampling intensity of the FIA base plots to evenly intensify the grid over FIA base hexagons, and to insure a degree of spatial separation between intensified samples by using a smaller hexagon grid. The SMNRA intensification has been used in conjunction with FIA base grid data to improve estimates and statistical confidence.

Intensified inventories should be spatially unbiased, usually grid-based, and are designed to capture the information needed to supplement the base-line grid. Nevertheless, more samples are often needed in addition to intensified inventory data for accuracy assessment, especially for under-represented classes.

Methods

In general, quantitative inventory data (e.g., FIA-base and intensified) can be used for many assessments or as complementary information for other projects. Mid-level vegetation mapping typically produces three layers of information: dominance type, canopy cover, and tree size. Since the inventory data are a true sample (systematic, random) of these characteristics across the landscape (i.e., a national forest, county, or state), the data can be used in ways that complement the mapping process, or as an independent data set to assess the accuracy of the maps, or both. For mid-level mapping purposes, there are several ways in which the inventory data can be used:

1. Understanding the proportional distributions of forest dominance types and tree sizes across a map project area for map unit design and intermediate map evaluation purposes
2. Designed-based (e.g., FIA and intensified) versus model-based area estimate comparisons of the final map products (non-site-specific)
3. Site-specific accuracy assessment

Discussed below are the methods used for data preparation and classification, non-site-specific area estimate comparison, and site-specific accuracy assessment for this project using the FIA base-level and intensified plot data. The combined set of base-FIA and SMNRA intensified plots used for this accuracy assessment are collectively referred to in the subsequent accuracy assessment subsections of this report as ‘inventory’ plots.

Data Preparation and Classification

The first step in the data preparation process was data acquisition. Before classification began, it was necessary to join the proper tables, query the data from IWFIA’s regional database, and calculate various variables used in this process. Quality control checks were run on previously populated and vetted statewide national databases to assure that plot-level and condition-level estimates (e.g., live basal area per acre estimates, understory vegetation species and lifeform cover estimates) were correct.

The next step was to assign dominance types to the plot/condition-level data (some plots have multiple conditions) in conjunction with the classification criteria outlined in the SMNRA

Existing Vegetation Keys¹³. This complicated step involved separating plots and their plot conditions into many categories in order to use the appropriate available information for a particular condition's characteristics. The FIA and intensified plot layout and an example scenario where more than one condition exists on a plot are illustrated in Appendix IX¹⁴.

Species-level canopy cover data were available for all lifeforms except trees. A variable collected on all plots "total live crown cover for all tree species" was used to determine necessary thresholds for forest and woodland dominance types. Basal area (BA) by species was used to calculate total crown cover by species, and then used with the key. The following summarizes the primary steps involved in assigning vegetation dominance types, tree size, and crown cover:

Vegetation dominance type steps included:

- Calculate live BA per acre estimates by species
- Convert to percentages of total live BA by species
- Identify species with plurality of percent live basal area
- Use live BA percentages as a surrogate in key for identifying species that are the most abundant in terms of relative cover
- Where necessary in key, use total cover to convert to absolute cover
- Determine general plot vegetation characteristics based upon vegetation groups and place into classes
- Based on plot and plot condition information, assign the appropriate dominance type, vegetation type, and vegetation group according to key to each condition
- Determine if plot data are relevant due to potential disturbance since plot measurement. If it is not relevant, determine other method of assigning dominance type information (imagery, plot photos, notes, etc.)

Tree Size steps included:

- Calculate live BA per acre estimates by diameter class by condition
- Convert to percentages of totals live BA by diameter class by species
- Identify diameter class with plurality of percent live basal area
- Assign diameter classes to plot/conditions

¹³ See

[Appendix III: Existing Vegetation Keys.](#)

¹⁴ See [Appendix IX: Diagram of FIA and SMNRA Intensified Plot.](#)

- Determine if plot data are relevant due to potential disturbance since plot measurement. If they are not relevant, determine other method of assigning tree size information (imagery, plot photos, notes, etc.)

Canopy cover steps included:

- Use total live tree cover (greater than 10 percent) variable to determine forest and woodland conditions
- If total live tree cover is less than 10 percent, then use understory veg cover estimates by lifeform and species to determine nonforest cover classes
- Determine if plot data are relevant due to potential disturbance since plot measurement. If they are not relevant, determine other method of assigning crown or shrub cover information (imagery, plot photos, notes, etc.)

Non-Site-Specific Accuracy Assessment

A non-spatial comparison of design-based (inventory) vs. model-based (mapped) area outputs is one way of assessing a final map. Such a comparison was in-part, the reason that the Forest Service management decision appeal was affirmed in the Mission Brush Case (Lands Council vs. McNair 2008). Design-based estimates such as FIA and intensified provide an excellent source of accuracy assessment information, since it is a true systematic random sample.

Stratification for Area Estimates

Area expansion factors are the area that a quantitative inventory plot represents at the population level. The stratification process is an important step in determining area estimates from inventory data as it provides an area representation from which area expansions can be determined. The following stratification crosswalk was used on the SMNRA to classify plots into generalized classes based upon their map-assigned strata (**Table 12**). The Vegetation Groups were classed into one of three strata, based upon their vegetation characteristics. Brown strata represented nonforest areas while Green represented forest areas. Woodland classes were given their own strata to offer a more refined filter, which was necessary due to the large woodland component.

Since the inventory plots used for this assessment provided spatially distributed, unbiased estimates and all data collection protocols were consistent, whether forest or nonforest, these data were considered a legitimate unbiased sample. There were a total of 244 plot/conditions used for the area estimation from a total of 230 inventory plot locations. As part of the plot data collection protocol, conditions are mapped and sampled separately for each plot because they are considered an area of relatively uniform ground cover (i.e., homogenous vegetation cover) which in turn allows area weights to be assigned using condition proportions. Based upon the area of the strata and the distribution of plots, an area expansion factor was applied to each plot based upon the strata value.

Table 12: A crosswalk of how inventory plots were grouped to generalized strata that were determined by their Vegetation Group Class. These general strata classifications help inform the inventory estimation process by assigning strata areas to plots.

Group Code	Vegetation Group	STRATA
A	Alpine	Brown
H	Herbland	Brown
N	Non- Vegetated/Sparse Vegetation	Brown
R	Riparian	Brown
S	Shrubland	Brown
C	Conifer Forest	Green
D	Deciduous Forest	Green
W	Woodland	Green/Brown

Site-Specific Accuracy Assessment

Another use for the quantitative inventory (FIA-base and intensified plots) is for conducting site-specific accuracy assessments on existing vegetation mid-level map products. All plots on the FIA base-level grid, as well as intensified plots collected by IWFIA, were used for this assessment. The use of all plots was necessary so that the systematic, unbiased nature of the

grid was not compromised. This assessment was completed by comparing the FIA and intensified subplot 1 center location¹⁵ to the spatially coincident mapped polygon feature.

It was determined that to best portray the map accuracy, the assessment would be performed on the final map features, and not the intermediate modeled segments, which serve as the building blocks for the final product. This resulted in polygons that were either at a minimum the same size as the segments, but more often larger, which allowed more of the plots to fit entirely within an evaluation unit and reduced the number of plots that straddled segments. Consequently, some polygons were quite large. Due to the inherent differences between the inventory sample design and map characteristics, and since all inventory plots were included in this assessment, the inventory sample design (e.g., size of plot), the field data collection protocols, and the defining attributes (forest type, tree size, tree cover density, etc.) associated with inventory vegetation condition boundaries were often not in alignment with the size or characteristics of the mid-level mapped polygon boundaries.

Prior accuracy assessments have used an involved process of analyzing inventory plots against the map polygons by applying decisions regarding the use of plots based upon their location within a polygon and near a polygon edge. In the case of the SMNRA assessment, it was decided to objectively use the subplot center location and condition without any adjustments. This process allows for a more objective and repeatable accuracy assessment.

Results

Non-Site-Specific Accuracy Assessment

Classification and stratification of inventory plot/conditions for estimating area estimates was performed, resulting in area estimates for vegetation group, vegetation type, tree size class (forest and woodland), and canopy cover class (tree and shrub).

Area Estimates Based on Inventory Plots

The source data set for this analysis was approximately nine years (2004 to 2012) of FIA data including All Condition Inventory (ACI) data, gathered to gain a representation of nonforest plots. It also included intensified plot data collected 2010-2012 by Interior West Forest Inventory and Analysis.

¹⁵ See [Appendix IX: Diagram of FIA and SMNRA Intensified Plot](#).

There were a total of 244 plot/conditions available for area estimation from a total of 230 inventory plot locations. When plots have more than one vegetation condition, condition-level plot data was used for area estimates. While the area classification focused on the condition level data, the site-specific accuracy assessment focused on plot level information and its spatial relationship to the mapped polygons.

Below are the summarized inventory data results for predicted area, percent area, and number of plot/conditions by the five map attributes (vegetation group, vegetation type, tree size class, tree canopy cover class, and shrub canopy cover class).

Vegetation Group Area Estimates

Approximately 64 percent of the SMNRA is in forest and woodland groups and approximately 36 percent are in nonforest conditions. The woodland class is the largest group with nearly half the area. Shrubland (31 percent) is the second largest vegetation group, while conifer covers 14 percent of the area. The SMNRA had no inventory plots representing riparian, deciduous, or alpine vegetation groups (**Table 13**).

Table 13: Inventory-estimated area (acres), percentage of total area, and number of plot/conditions by forest/nonforest category and vegetation group on the SMNRA.

Vegetation Group	Area (ac)	Percent Area	No. of plot/conditions (n)
Forest and Woodland			
Deciduous Forest	0	0.0	
Conifer Forest	44,278	14.0	30
Woodland	158,108	49.9	114
Sub-total	202,386	63.9	144
Nonforest			
Alpine Vegetation	0	0.0	
Herbland	4,926	1.6	4
Non-Vegetated/Sparse Vegetation	11,069	3.5	12
Riparian Vegetation	0	0.0	
Shrubland	98,490	31.1	84
Upland Herbaceous	0	0.0	
Sub-total	114,485	36.1	100
Total	316,871	100.0	244

Vegetation Type Area Estimates

Pinyon-Juniper/Montane Shrub is the largest map unit at approximately 30 percent of the SMNRA (by acres), followed by Blackbrush Shrubland (21 percent), Pinyon-Juniper/Desert Shrub (13 percent), and Mountain Shrubland (7 percent). The remaining map units all have less than 6 percent area for each map unit. Four map units had no classified inventory samples (Upland Herbaceous, Aspen, Alpine Vegetation, Riparian Vegetation), which reflects the relative scarcity of occurrence of these types across the area (**Table 14**).

Table 14: Inventory-estimated area (acres), percentage of total area, and number of plot/conditions by forest/nonforest category and vegetation type on the SMNRA.

Vegetation Type	Area (ac)	Percent Area	No. of plot/conditions (n)
Forest and Woodland			
Bristlecone Pine	9,832	3.1	7
Bristlecone Pine/Limber Pine	12,412	3.9	8
Gambel Oak	3,463	1.1	3
Mountain Mahogany Mix	17,935	5.7	13
Pinyon-Juniper/Desert Shrub	42,002	13.3	30
Pinyon-Juniper/Montane Shrub	94,708	29.9	68
Ponderosa Pine	4,005	1.3	3
White Fir/Ponderosa Pine	18,029	5.7	12
Sub-total	202,386	63.9	144
Nonforest			
Annual Herbaceous	4,926	1.6	4
Barren/Sparse Vegetation	9,606	3.0	10
Blackbrush Shrubland	65,083	20.5	55
Developed	1,463	0.5	2
Mojave Shrubland	8,741	2.8	7
Mountain Shrubland	22,407	7.1	19
Rock Outcrop Shrubland	2,259	0.7	3
Sub-total	114,485	36.1	100
Total	316,871	100.0	244

Tree Size Class Area Estimates

Tree size class area was estimated for forest, woodland, and nonforest classes. The forest classes include Bristlecone Pine, Bristlecone Pine/Limber Pine, Ponderosa Pine, and White Fir/Ponderosa Pine map units. The woodland classes include Gambel Oak, Mountain Mahogany Mix, Pinyon-Juniper/Desert Shrub, and Pinyon-Juniper/Montane Shrub map units. Nonforest (36 percent) was the most common class, followed by Woodland Tree Size Class 1 (27 percent), which represents the smallest diameter woodland sites with DRCs less than 11.9 inches, and Woodland Tree Size Class 3 (13 percent), with the largest diameter woodland sites with DRCs greater than 18 inches. Forest size classes accounted for approximately 14 percent of total area (**Table 15**).

Table 15: Inventory-estimated area (acres), percentage of total area, and number of plot/conditions by tree size class for forest and woodland classes on the SMNRA.

Tree Size Code	Tree Size Class	Area (ac)	Percent Area	No. of plot/conditions (n)
FTS1	Forest (0 -8.9" DBH)	9,333	3.0	6
FTS2	Forest (9 - 20.9" DBH)	22,244	7.0	15
FTS3	Forest (21"+ DBH)	12,701	4.0	9
WTS1	Woodland (0 - 11.9" DRC)	86,583	27.3	62
WTS2	Woodland (12 - 17.9" DRC)	30,564	9.6	22
WTS3	Woodland (18"+ DRC)	40,961	12.9	30
NF	Nonforest	114,485	36.1	100
Total		316,871	100.0	244

Canopy Cover Class Area Estimates

Canopy cover area was estimated for tree and shrubland canopies. The shrubland cover classes (SC) include the Blackbrush Shrubland, Mojave Shrubland, Mountain Shrubland, and Rock Outcrop Shrubland vegetation types. The tree cover classes (TC) include Bristlecone Pine, Bristlecone Pine/Limber Pine, Gambel Oak, Mountain Mahogany Mix, Pinyon-Juniper/Desert Shrub, Pinyon-Juniper/Montane Shrub, Ponderosa Pine, and White Fir/Ponderosa Pine vegetation types. The most prevalent cover class is TC2 at approximately 29 percent, followed by TC1 (19 percent), TC3 (16 percent), and SC3 (13 percent). The primary reason for large representation of areas in the tree cover classes is the prevalence of Pinyon and Juniper on the SMNRA (**Table 16**).

Table 16: Inventory-estimated area (acres), percentage of total area, and number of plot/conditions by tree and shrub canopy cover class on the SMNRA.

Canopy Cover Code	Canopy Cover Class	Area (ac)	Percent Area	No. of plot/conditions (n)
NC	No canopy cover	15,995	5.0	16
SC1	SCC 10 - 20%	28,077	8.9	23
SC2	SCC 21 - 30%	29,792	9.4	26
SC3	SCC >= 31%	40,621	12.8	35
TC1	TCC 10 - 20%	59,074	18.6	45
TC2	TCC 21 - 40%	92,391	29.2	64
TC3	TCC 41 - 70%	50,921	16.1	35
TC4	TCC >= 71%	0	0.0	0
Total		316,871	100.0	244

Comparisons of Mapped to Inventory Area Estimates

In general, map units with many classes such as vegetation type tend to have more discrepancies between the mapped area estimates and field sampled occurrences. This is probably due to more and finer thresholds hindering recognition of class spectral signatures, and may also be due to limitations in the number of accuracy assessment sites available from quantitative inventory plots. It should also be noted that other map units with few classes (such as tree size or canopy cover) are typically difficult to map accurately.

All mapped areas in the subsequent tables are based upon acreage values calculated in the Region 4 Albers Equal Area projection and the version of Automated Lands Project (ALP) Forest Service ownership that is currently archived in the project record. Changes in the ALP dataset as well as area calculations using other spatial references will result in variations of total acreages. Following are comparisons of inventory and mapped percentages of total area results.

Vegetation Group Comparisons

Summaries were created to compare inventory-derived estimates and mapped acreages (**Table 17**, **Figure 7**, and **Figure 8**). Woodland vegetation groups compose more than half of the map and just below half of the inventory plot data. Agreement between the Woodland and Shrubland groups was relatively close. The major discrepancy between inventory and mapped groups was in the Non-Vegetated/Sparse Vegetation class. It appears that a fair amount of areas classified by inventory as Non-Vegetated/Sparse Vegetation was mapped as Woodland, Herbland, or Shrubland classes. The discussions around inventory confidence interval estimates and the error matrix component of this report will further elaborate on these gaps.

Table 17: Mapped and inventory-estimated area by vegetation group on the SMNRA.

Veg Group Code	Veg Group Class	Map Acres	Map Percent	Inventory Acres	Inventory Percent	Acreage Difference	Percent Difference
W	Woodland	163,271	51.5	158,108	49.9	5,163	1.6
S	Shrubland	102,561	32.4	98,490	31.1	4,072	1.3
C	Conifer Forest	42,367	13.4	44,278	14.0	-1,911	-0.6
N	Non-Vegetated/ Sparse Vegetation	835	0.3	11,069	3.5	-10,234	-3.2
H	Herbland	6,562	2.1	4,926	1.6	1,635	0.5
D	Deciduous Forest	698	0.2	0	0.0	698	0.2
A	Alpine	370	0.1	0	0.0	370	0.1
R	Riparian	206	0.1	0	0.0	206	0.1
Total		316,871	100.0	316,871	100.0	N/A	N/A

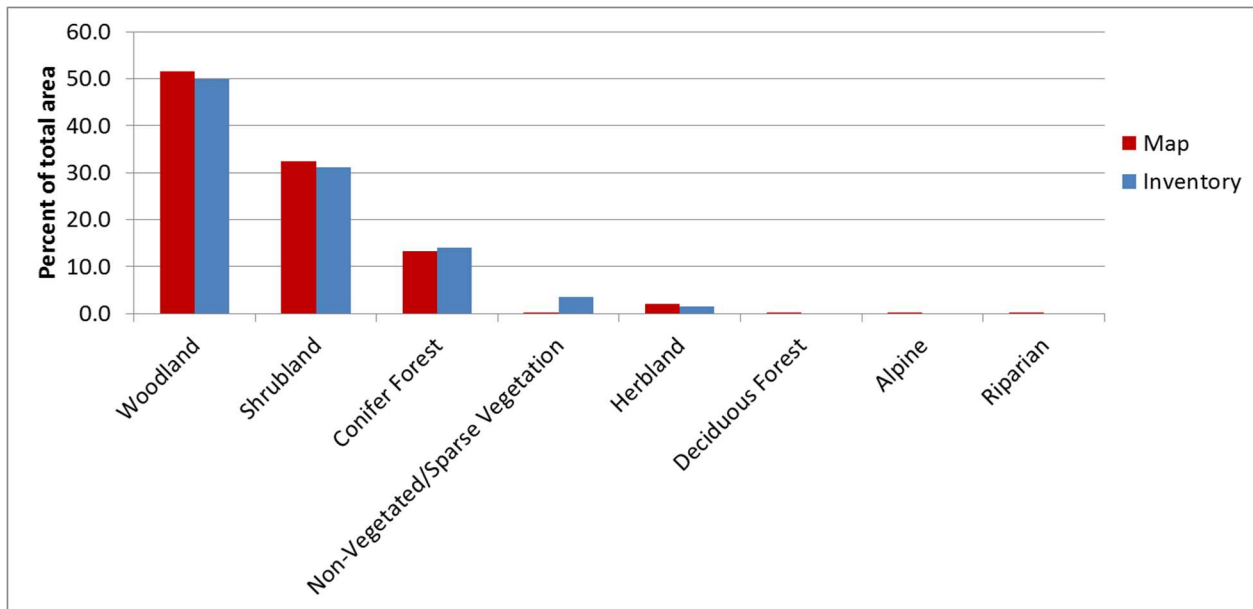


Figure 7: Comparison of mapped and inventory-estimated area as percentage of total area, by vegetation group on the SMNRA.

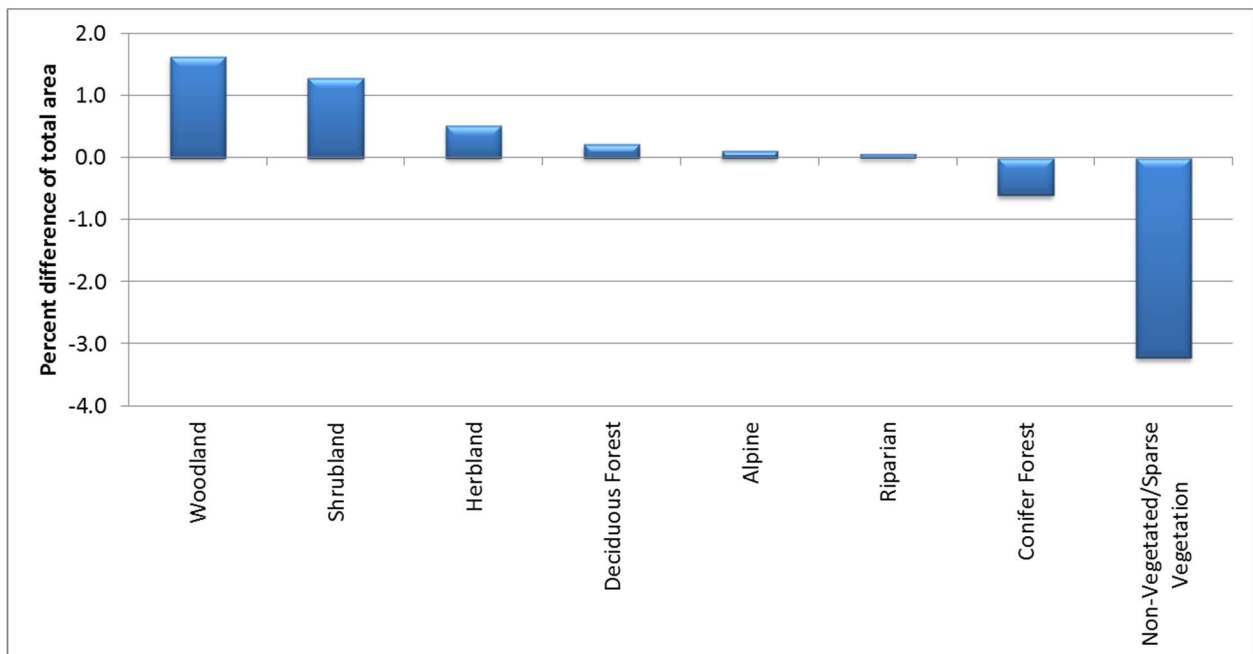


Figure 8: Comparison of mapped and inventory-estimated area as the difference in percentage of total area, by vegetation group on the SMNRA. A positive difference indicates mapped acres exceed inventory acres for that group; a negative difference indicates inventory acres exceed mapped acres.

Confidence Interval (95 Percent Standard Error) for Vegetation Groups

Using the Forest Inventory Estimation Tool (FIESTA) (Frescino et al. 2012), it is possible to generate 95 percent standard error values around area estimates of sampled inventory data. By definition, these standard error values represent that there is a 95 percent statistical likelihood that the value ranges are within the bounds of the confidence intervals. It is important to note that standard error values are influenced by sample size. In some cases, map classes were barely or not represented within the inventory data. The FIESTA-based estimates are more appropriate for classes with high sampled area representations. The bounding values give us a better idea of where the area estimates should fall, which informs the accuracy assessment of the maps. It was noted earlier in this report that it appears that Non-Vegetated/Sparse Vegetation areas were mapped as Woodland, Shrubland, and Herbland classes. The error matrices presented later in this report help to elaborate where confusion occurred in the mapping process. Due to the small number of groups and relatively large number of samples, mapped areas fell within the confidence intervals for all groups except Non-Vegetated/Sparse Vegetation (Figure 9).

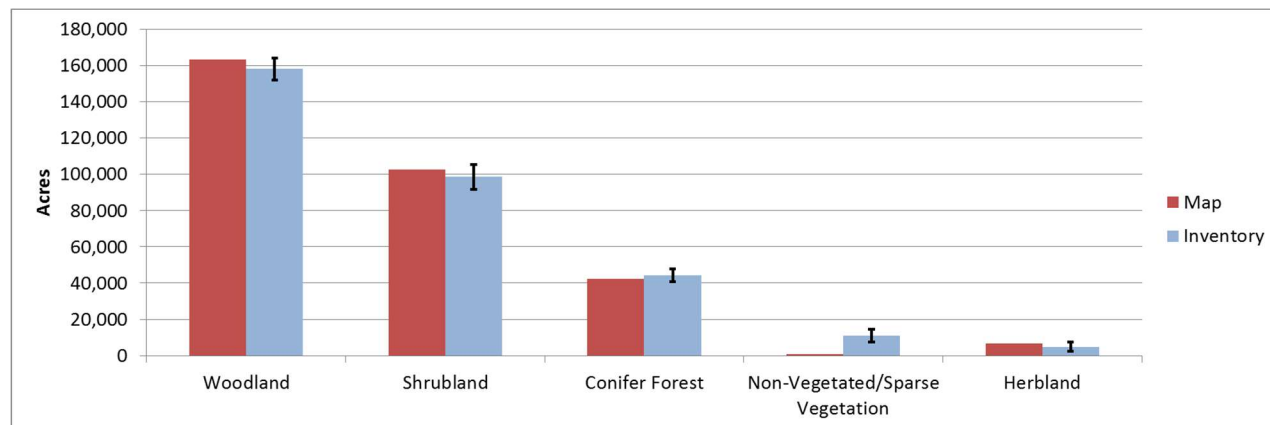


Figure 9: Comparison of mapped and inventory-estimated area as percentage of total area, by vegetation group on the SMNRA, with 95 percent standard error bars derived from FIESTA. Groups with low proportions are omitted.

Vegetation Type Comparisons

Vegetation types were compared between the mapped and inventory-predicted areas (Table 18, Figure 10, and Figure 11). There was good agreement between the inventory and the map for forest and woodland map units combined, and nonforest map units combined, with only a two percent difference; nevertheless, there were some notable differences in percent area for some of the ten most common map units. The mapped proportions of Blackbrush Shrubland,

Pinyon-Juniper/Desert Shrub, and White Fir/Ponderosa Pine were each at least two percentage points more than the corresponding inventory values (**Figure 10**). For Mountain Mahogany Mix, the mapped proportion was more than two points less than the inventory estimates.

Barren/Sparse Vegetation was also mapped at a lower percentage than the inventory estimate. Other classes were mapped in closer proportion to inventory-derived estimates. Comparisons for map units with less than ten inventory plot/conditions are not recommended.

Misclassifications and confusion areas will be outlined in the error matrix portion of the report.

Table 18: Mapped and inventory-estimated area by vegetation type on the SMNRA.

Vegetation Class	Code	Map Acres	Map Percent	Inventory Acres	Inventory Percent	Acreage Difference	Percent Difference
Pinyon-Juniper/ Montane Shrub	PJ/MT	95,704	30.2	94,708	29.9	996	0.3
Blackbrush Shrubland	BBSH	76,034	24.0	65,083	20.5	10,951	3.5
Pinyon-Juniper/ Desert Shrub	PJ/DE	50,349	15.9	42,001	13.3	8,348	2.6
Mountain Shrubland	MS	19,243	6.1	22,407	7.1	-3,164	-1.0
White Fir/ Ponderosa Pine	WF/PP	24,707	7.8	18,029	5.7	6,678	2.1
Mountain Mahogany Mix	MMmix	10,723	3.4	17,935	5.7	-7,212	-2.3
Bristlecone Pine/ Limber Pine	BC/LM	6,860	2.2	12,412	3.9	-5,552	-1.8
Bristlecone Pine	BCP	9,057	2.9	9,832	3.1	-775	-0.2
Barren/Sparse Vegetation	BR/SV	732	0.2	9,606	3.0	-8,874	-2.8
Mojave Shrubland	MOSH	5,167	1.6	8,741	2.8	-3,574	-1.1
Annual Herbaceous	AHE	3,672	1.2	4,926	1.6	-1,251	-0.4
Ponderosa Pine	PP	1,743	0.5	4,005	1.3	-2,262	-0.7
Gambel Oak	GO	6,496	2.0	3,463	1.1	3,033	1.0
Rock Outcrop Shrubland	ROSH	2,118	0.7	2,259	0.7	-141	-0.0
Developed	DEV	100	0.0	1,463	0.5	-1,363	-0.4
Upland Herbaceous	UHE	2,890	0.9	0	0.0	2,890	0.9
Aspen	AS	698	0.2	0	0.0	698	0.2

Alpine Vegetation	ALP	370	0.1	0	0.0	370	0.1
Riparian Vegetation	RV	206	0.1	0	0.0	206	0.1
Water	WA	3	0.0	0	0.0	3	0.0
Total		316,871	100.0	316,871	100.0	N/A	N/A

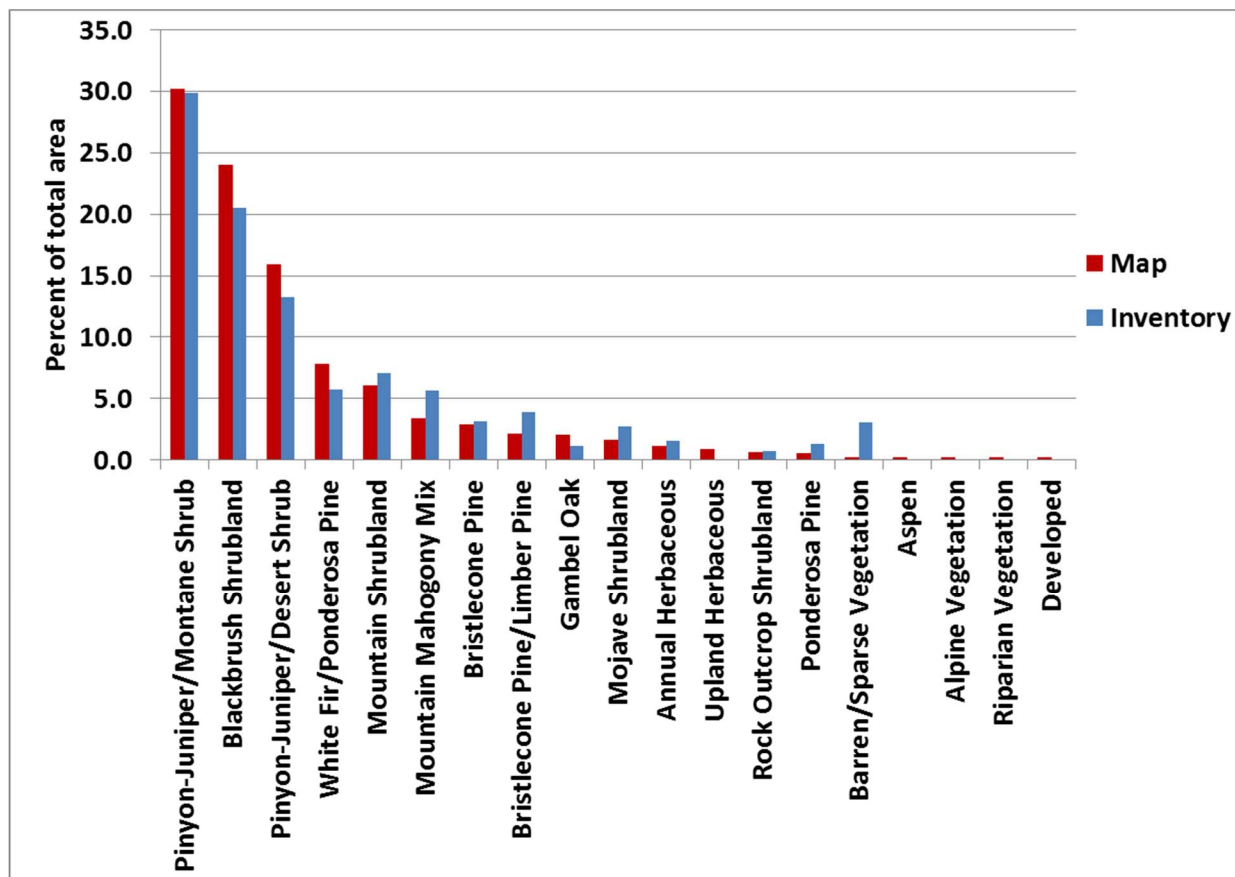


Figure 10: Comparison of mapped and inventory-estimated area as percentage of total area, by vegetation type on the SMNRA.

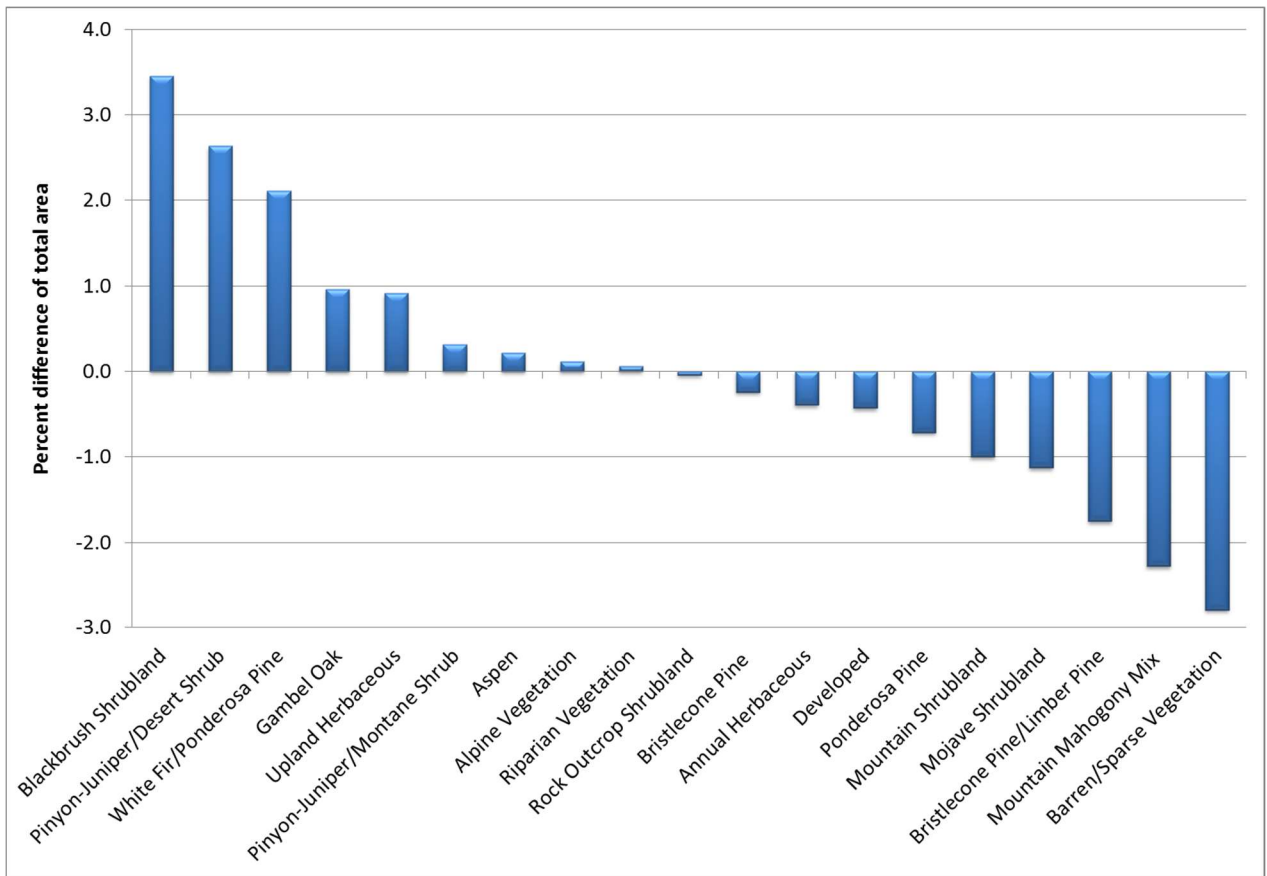


Figure 11: Comparison of mapped and inventory-estimated area as the difference in percentage of total area, by vegetation type on the SMNRA. A positive difference indicates mapped acres exceed inventory acres for that type; a negative difference indicates inventory acres exceed mapped acres.

Confidence Interval (95 Percent Standard Error) for Vegetation Type

Use of the FIESTA area estimator for vegetation type begins to reveal the strengths and weaknesses of the mapping process when additional classes are introduced into the modeling process from vegetation group to vegetation type. As expected, comparisons of the mapped areas to their expected confidence intervals distinguishes the classes that were modeled well in the mapping process from those classes that were more difficult to model (**Figure 12**). The mapped areas for Pinyon-Juniper/Montane Shrub, Mountain Shrubland, Bristlecone Pine, and Annual Herbaceous vegetation types fell within the expected 95 percent confidence intervals. The Blackbrush Shrubland, Pinyon-Juniper/Desert Shrub, White Fir/Ponderosa Pine, Mountain Mahogany Mix, Bristlecone Pine/Limber Pine, Mojave Shrubland, Ponderosa Pine, and Gambel Oak mapped areas fell outside of their confidence intervals.

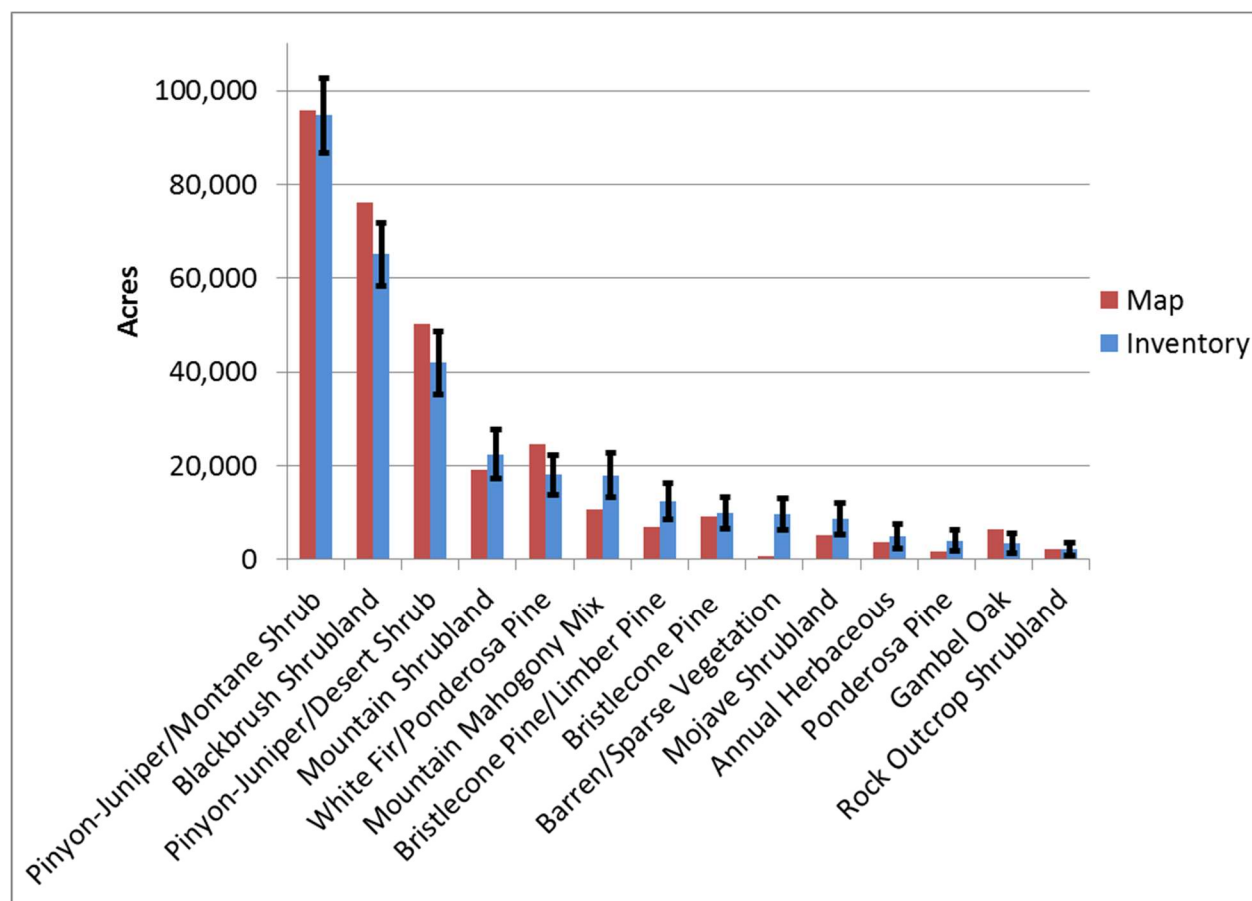


Figure 12: Comparison of mapped and inventory-estimated area as percentage of total area, by vegetation type on the SMNRA, with 95 percent standard error bars derived from FIESTA. Types with low proportions are omitted.

Tree Size Class Comparisons

The map and inventory-estimated areas for tree size class were compared (**Table 19, Figure 13, and Figure 14**). The Nonforest class was the largest for both the inventory and the map, and had relatively good agreement between the two estimates. This is likely due to similar nonforest masking procedures in the early stratification process. The woodland classes showed fairly high discrepancies between mapped and field-estimated acreages. The inventory data show that most of the woodland areas fall within the smallest class (W-TS1); however, the mapped areas are much higher in the larger classes (W-TS2 and W-TS3). A similar trend occurs in the forest classes, in which the inventory data show that the mapping overestimates the size of the larger classes. Both of these trends suggest challenges in the geospatial modeling of size classes for woodland and forest systems.

Table 19: Mapped and inventory-estimated area by forest and woodland tree size class on the SMNRA.

Size Code	Size Class	Map Acres	Map Percent	Inventory Acres	Inventory Percent	Acreage Difference	Percent Difference
FTS1	Forest (0 - 8.9" DBH)	3,843	1.2	9,333	2.9	-5,490	-1.7
FTS2	Forest (9 - 20.9" DBH)	24,052	7.6	22,244	7.0	1,808	0.6
FTS3	Forest (21"+ DBH)	15,171	4.8	12,701	4.0	2,470	0.8
NF	Nonforest	110,535	34.9	114,485	36.1	-3,950	-1.2
WTS1	Woodland (0 - 11.9" DRC)	42,460	13.4	86,583	27.3	-44,123	-13.9
WTS2	Woodland (12 - 17.9" DRC)	52,331	16.5	30,564	9.6	21,767	6.9
WTS3	Woodland (18"+ DRC)	68,481	21.6	40,961	12.9	27,520	8.7
Total		316,871	100.0%	316,871	100.0%	N/A	N/A

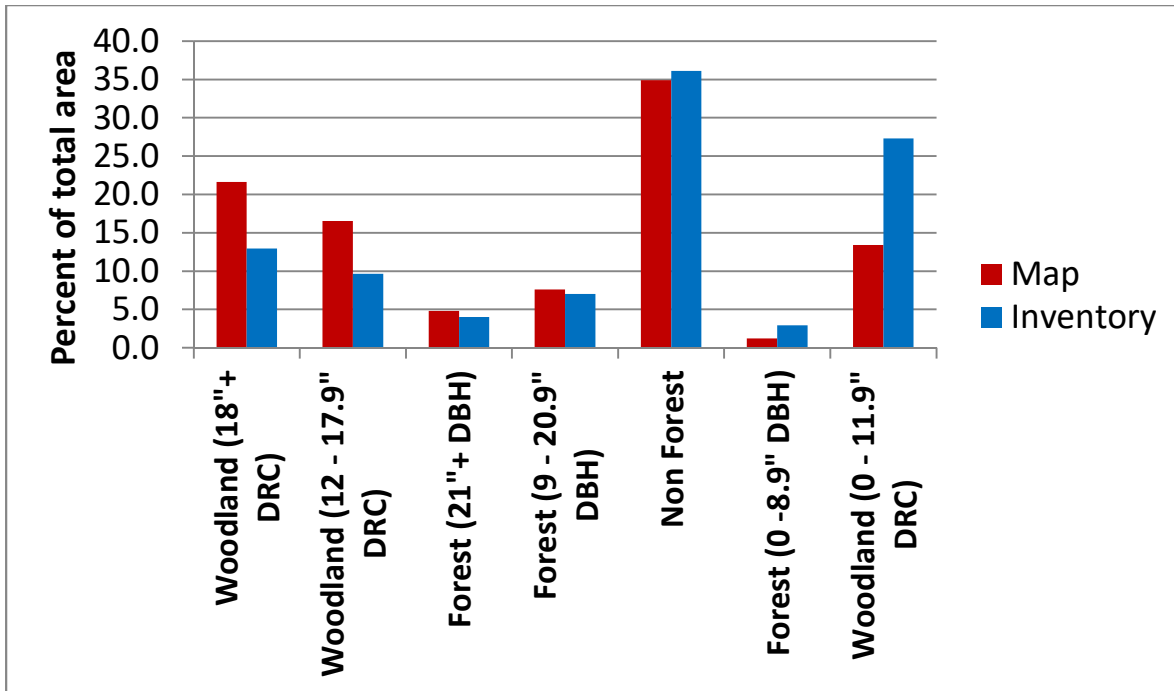


Figure 13: Comparison of mapped and inventory-estimated area as percentage of total area, by forest and woodland tree size class on the SMNRA.

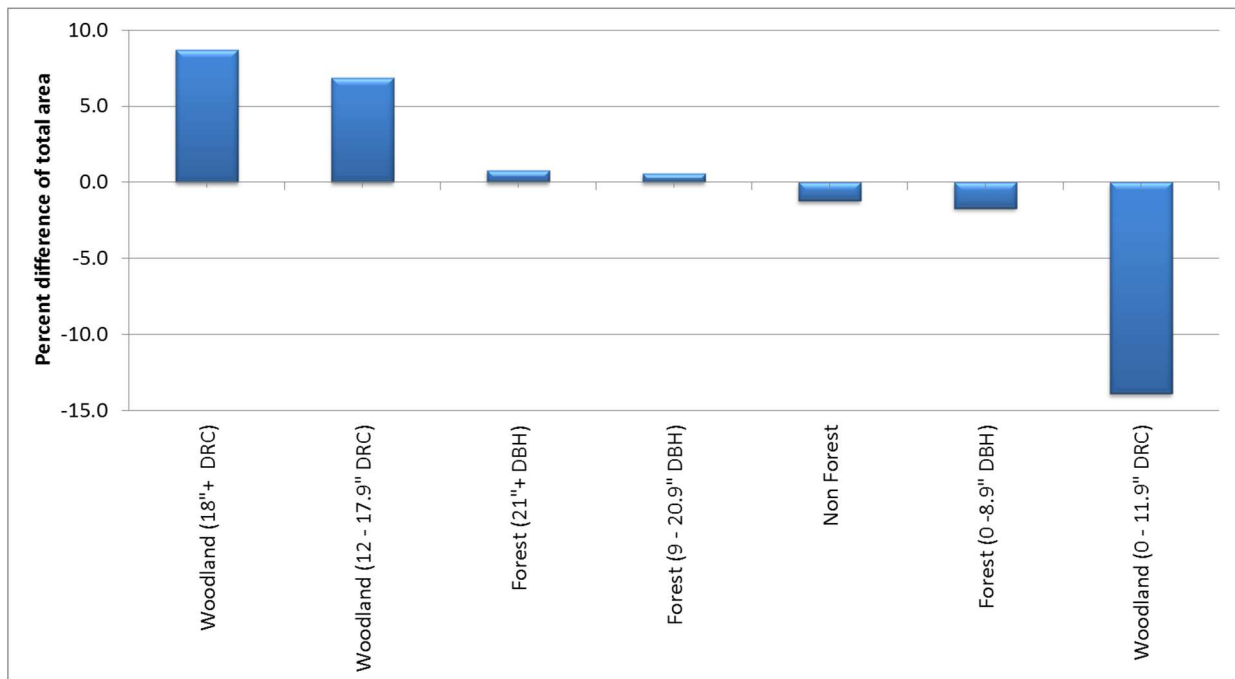


Figure 14: Comparison of mapped and inventory-estimated area as the difference in percentage of total area, by tree size class on the SMNRA. A positive difference indicates mapped acres exceed inventory acres for that class; a negative difference indicates inventory acres exceed mapped acres.

Confidence Interval (95 Percent Standard Error) for Tree Size Class

FIESTA-based estimates around the inventory areas for size class show that only two classes, FTS2-Forest (9-20.9" DBH) and FTS3-Forest (21" + DBH) fell within the 95 percent standard error for mapped area versus inventory area. All of the woodland classes fell outside of their confidence intervals. It is important that users of the map understand the limitations of mapping forest and woodland size classes, such as estimating tree size from aerial imagery, or sampling errors associated with measuring size classes in the field.

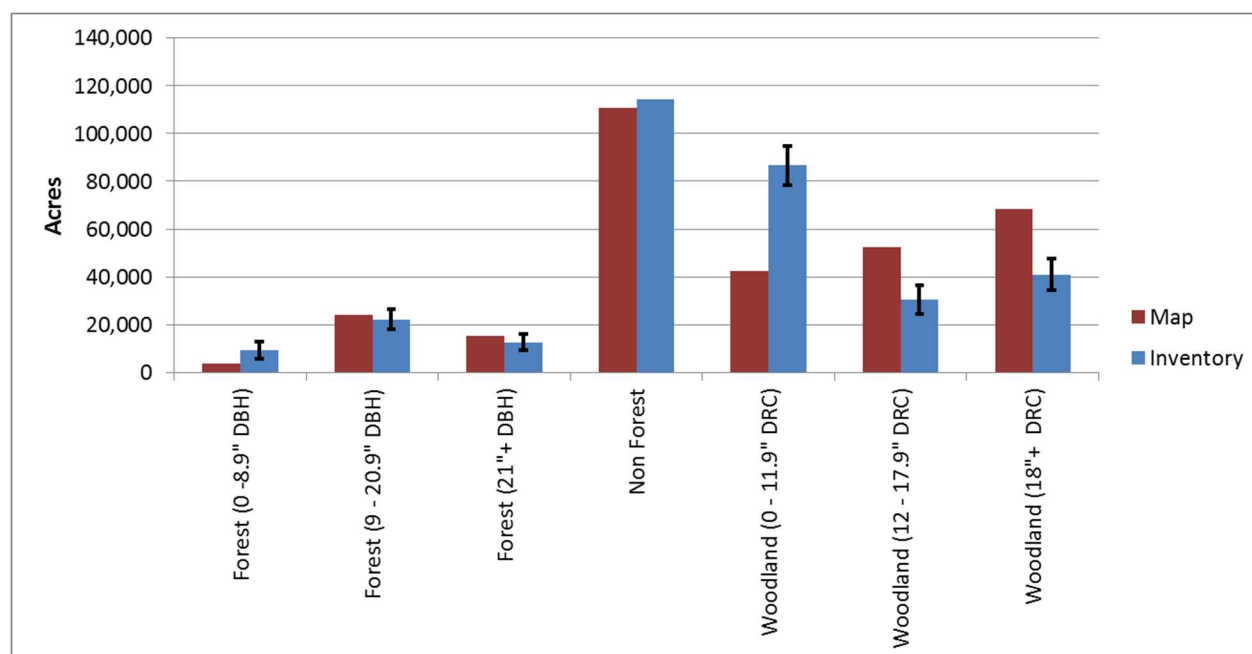


Figure 15: Comparison of mapped and inventory-estimated area as percentage of total area, by tree size class on the SMNRA, with 95 percent standard error bars derived from FIESTA.

Tree Canopy Cover Comparisons

There was a general trend of mapping tree canopy percentage lower than that based upon inventory plots. The lower cover classes (TC1 and TC2) were mapped with more area than the inventory corresponding classes. However, the inventory estimate for the more dense cover class (TC3) was much higher than the mapped area for that class (**Table 20, Figure 16, and Figure 17**). There were no inventory plots in the highest cover class (TC4). As a result of these

findings, an investigation into using aerial photo interpretation methods for estimating tree canopy cover was performed¹⁶.

Table 20: Mapped and inventory-estimated area by tree canopy cover class on the SMNRA.

CC Code	Canopy Cover Class	Map Acres	Map Percent	Inventory Acres	Inventory Percent	Acreage Difference	Percent Difference
TC1	TCC 10 - 20%	86,431	27.3	59,074	18.6	27,357	8.6
TC2	TCC 21 - 40%	101,765	32.1	92,391	29.2	9,374	3.0
TC3	TCC 41 - 70%	17,389	5.5	50,921	16.1	-33,532	-10.6
TC4	TCC >= 71%	751	0.2	0	0.0	751	0.2

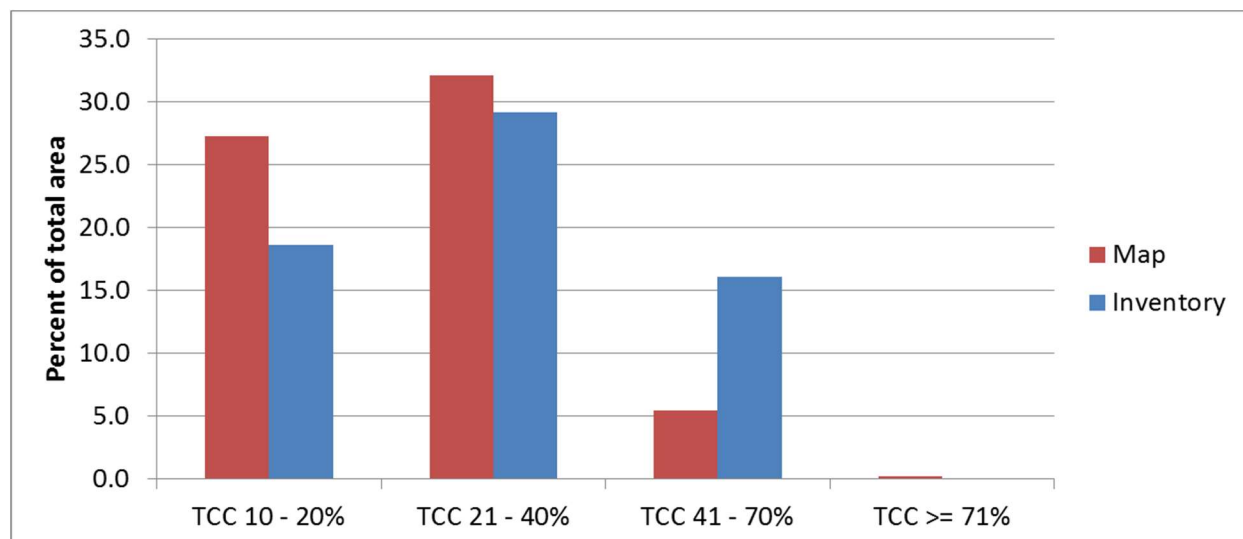


Figure 16: Comparison of mapped and inventory-estimated area as percentage of total area, by tree canopy cover class on the SMNRA.

¹⁶ See [Appendix X: Tree Canopy Cover Assessment](#).

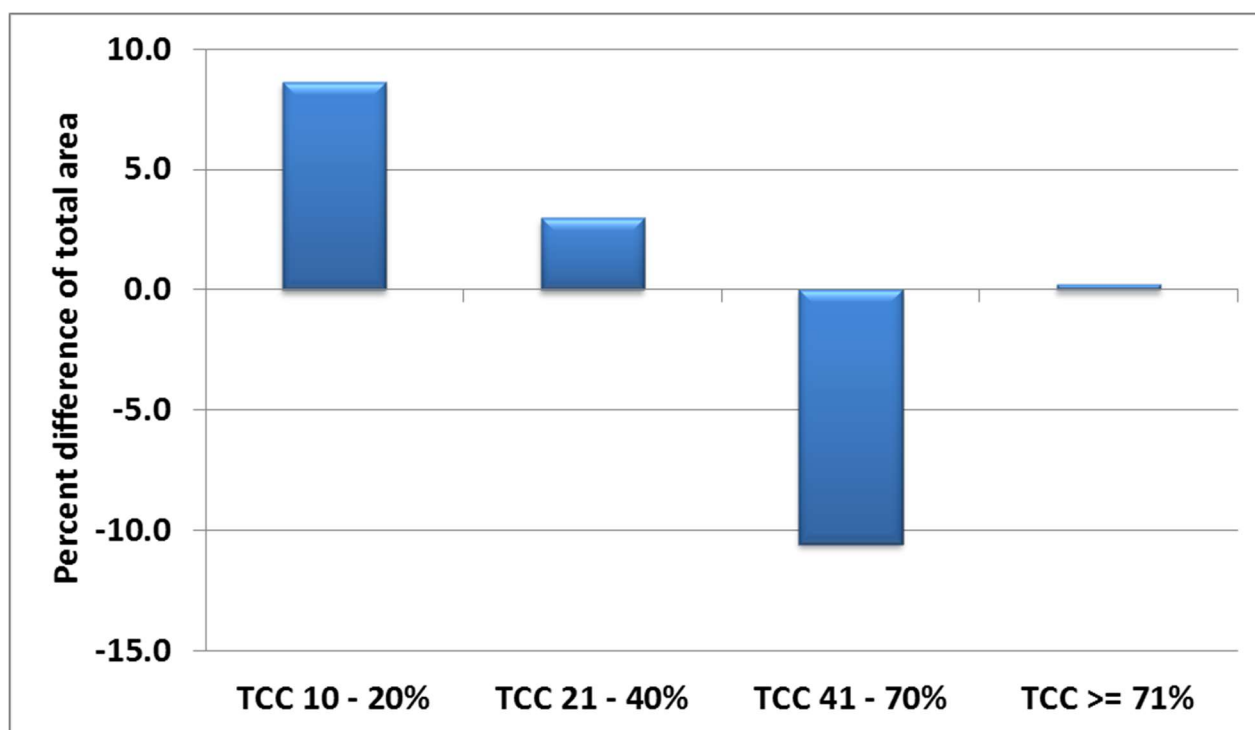


Figure 17: Comparison of mapped and inventory-estimated area as the difference in percentage of total area, by tree canopy cover class on the SMNRA. A positive difference indicates mapped acres exceed inventory acres for that class; a negative difference indicates inventory acres exceed mapped acres.

Shrub Canopy Cover Comparisons

The map and inventory-estimated areas for shrub cover class were compared (**Table 21**, **Figure 18**, and **Figure 19**). More map polygons were classified in the middle shrub class (SC2), while the inventory showed a wider distribution between the larger and smaller classes.

Table 21: Mapped and inventory-estimated area by shrub canopy cover class on the SMNRA.

CC Code	Canopy Cover Class	Map Acres	Map Percent Area	Inventory Acres	Inventory Percent	Acreage Difference	Percent Difference
SC1	SCC 10 - 20%	20,298	6.4	28,077	8.9	-7,779	-2.5
SC2	SCC 21 - 30%	50,977	16.1	29,792	9.4	21,185	6.7
SC3	SCC >= 31%	31,493	9.9	40,621	12.8	-9,128	-2.9

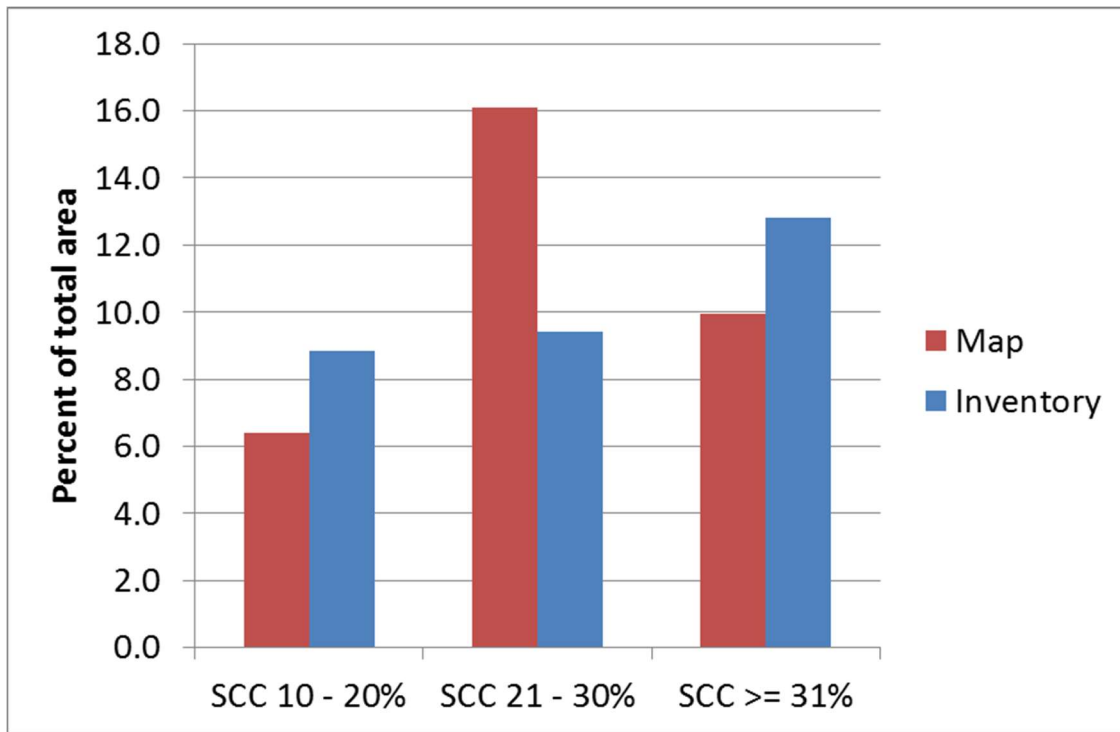


Figure 18: Comparison of mapped and inventory-estimated area as percentage of total area, by shrub canopy cover class on the SMNRA.

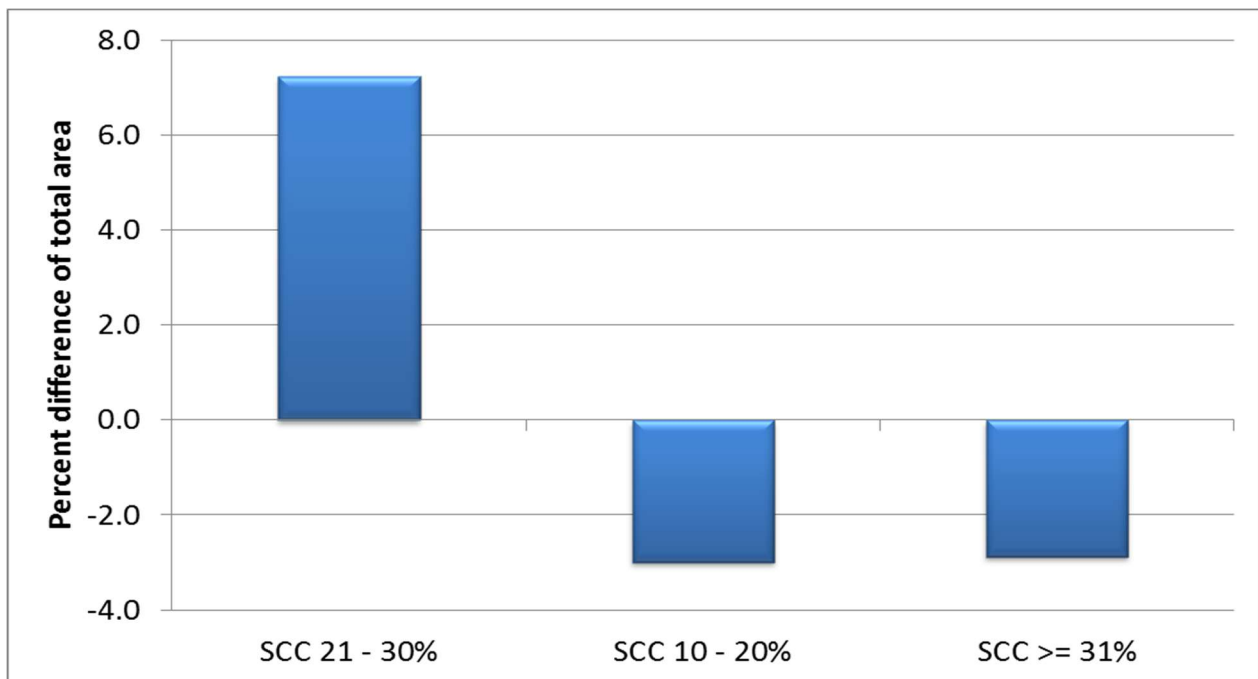


Figure 19: Comparison of mapped and inventory-estimated area as the difference in percentage of total area, by shrub canopy cover class on the SMNRA. A positive difference indicates mapped acres exceed inventory acres for that class; a negative difference indicates inventory acres exceed mapped acres.

Confidence Interval (95 Percent Standard Error) for Canopy Cover Class

The expected acreages and range of 95 percent confidence interval standard error based upon the inventory data for each cover class were compared (**Figure 20**). The mapped Tree Canopy Class 2 (TCC 21-40%) areas fell close to its 95 percent confidence interval range based upon the inventory data. Shrub Canopy Class 1 (SCC 10-20 %) and Shrub Canopy Class 3 (SCC $\geq 31\%$) were also fairly close to their target confidence intervals. The other classes fell more outside the range of expected cover class values based upon the inventory data. Further analysis on the assessment of tree canopy cover class using photo interpretation methods is presented in Appendix X¹⁷.

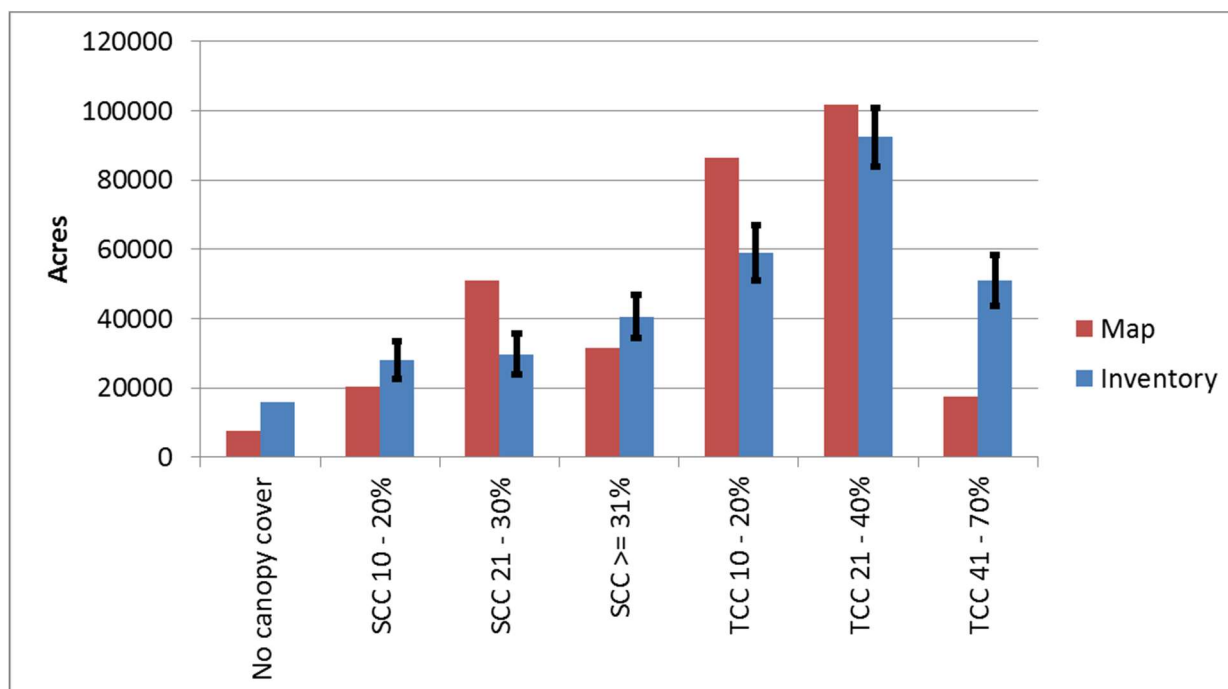


Figure 20: Comparison of mapped and inventory-estimated area as percentage of total area, by canopy cover class on the SMNRA, with 95 percent standard error bars derived from FIESTA. Classes with low proportions are omitted.

¹⁷ See [Appendix X: Tree Canopy Cover Assessment](#).

Site-Specific Accuracy Assessment

Accuracy assessments are an essential part of any remote sensing project, used not only for comparing different mapping methods and sensors, but also for providing information on the reliability and usefulness of remote sensing techniques for a particular application. Most importantly, accuracy assessments support the mapped information used in the decision making process by providing a measure of the reliability of the mapped classes, and allowing users to understand the map's limitations (Nelson et al. in press).

The Error Matrix

The error (confusion) matrix is a standard tool used for presenting results of an accuracy assessment. In general, it is a square array where both the classified reference (observed) and image (mapped) data are ordered and compared for class agreement on the diagonally intersected cells; typically rows in the matrix represent the classified image data and columns in the reference data represent the observed data (Story and Congalton 1986). The error matrix can be used to determine the accuracy of classes and the degree of confusion between classes.

Table 22 consists of an error matrix for vegetation groups for the SMNRA. In this table, the *observed* classes (inventory plots) are presented in the columns and the *mapped* classes in the rows. The highlighted diagonal cells tally the number of inventory plots that are in agreement with the intersected mapped classes. Percent class accuracies are calculated by dividing the number of correct classifications (diagonal cells) by each class total. For each class there are two main types of accuracies generated by the error matrix. "User's accuracy" indicates errors of commission; this is where a class has been mapped in places where it does not exist. "Producer's accuracy" indicates errors of omission; this is where a class has not been mapped but exists on the ground.

Vegetation Group Error Matrix and Accuracies

The Woodland vegetation group had the highest producer's accuracy at 93 percent, followed by Conifer Forest and Shrubland groups at 86 percent. Herbland had a small area representation and a lower accuracy score of 50 percent. The Non-Vegetated/Sparse Vegetation group also had a lower producer's accuracy of 10 percent; likely due to variations in patch size in the map polygons. It was mentioned earlier in the report that the mapped versus inventory areas for this class were quite different. The Alpine, Herbland, and Non-Vegetated/Sparse Vegetation all had low inventory sample sizes and map area representations. The confusion appears to be within the Conifer Forest, Woodland, and Shrubland classes. It can be difficult to separate those classes, particularly within transition

zones between classes. In addition, inventory plots and vegetation group polygons may encompass multiple vegetation groups, leading to additional confusion. The overall user's and producer's accuracies for the vegetation group classification were 85 percent.

Table 22: Error matrix showing user's and producer's percent accuracies by vegetation group on the SMNRA.

		INVENTORY PLOTS							
Map Group		Alpine	Conifer Forest	Herbland	Non- Vegetated/Sparse Vegetation	Shrubland	Woodland	Total	User's Percent Accuracy
MAP CLASS	Alpine				1			1	N/A
	Conifer Forest		25				2	27	93
	Herbland			2	2			4	50
	Non- Vegetated/Sparse Vegetation				1			1	100
	Shrubland		2	2	6	68	6	84	81
	Woodland		2			11	100	113	89
	Total	0	29	4	10	79	108	230	85
	Producer's Percent Accuracy	N/A	86	50	10	86	93	85	

Vegetation Type Error Matrix and Accuracies

Vegetation type accuracy assessment results show a story of the complexity of mapping more refined classes than the general vegetation groups (**Table 23**). As expected, accuracies decline due to a larger number of classes and distinctions made to account for a greater variety of vegetation types. The overall accuracy for the map was approximately 67 percent, with clear distinctions between certain classes. Blackbrush Shrubland and Bristlecone Pine were well mapped; however, Bristlecone Pine had a low area representation of six plots. Pinyon-Juniper/Montane Shrub and White fir/Ponderosa Pine have 78 percent and 75 percent

producer's accuracy scores, respectively. In other classes, the results varied, with lower producer's accuracies for Gambel Oak, Ponderosa Pine, Mojave Shrubland and Annual Herbaceous. Gambel Oak had confusion with Mountain Shrubland. Ponderosa Pine had confusion with the White Fir/Ponderosa Pine type. Confusion often arises when mixed classes are created, which makes it difficult to discern spectral signature differences. The Mojave Shrubland was confused with the Blackbrush Shrubland. The Pinyon-Juniper/Desert Shrub and Pinyon-Juniper/Montane Shrub also demonstrated confusion with each other. A fundamental rule of mapping and accuracy assessments asserts that the larger the number of classes, the lower the accuracies will likely be. It is important to note that the mapping based on remotely sensing data rely upon imagery and topographic data to model vegetation. Similarities in spectral information between classes often lead to confusion between those classes. It is quite difficult to separate certain mixed classes due to the blending of spectral signatures when two different vegetation types exist together within a stand.

Table 23: Error matrix showing user's and producer's percent accuracies by vegetation type on the SMNRA.

		INVENTORY PLOTS																		
MAP UNIT CLASS	Map Unit	Alpine Vegetation	Annual Herbaceous	Barren/ Sparse Vegetation	Blackbrush Shrubland	Bristlecone Pine	Bristlecone Pine/ Limber Pine	Developed	Gambel Oak	Mojave Shrubland	Mountain Shrubland	Mountain Mahogany Mix	Pinyon-Juniper/ Desert Shrub	Pinyon-Juniper/ Montane Shrub	Ponderosa Pine	Rock Outcrop Shrubland	Upland Herbaceous	White Fir/ Ponderosa Pine	Total	User's Percent Accuracy
	Alpine Vegetation			1															1	0
	Annual Herbaceous		1																1	100
	Barren/Sparse Vegetation																		0	N/A
	Blackbrush Shrubland		1	4	49					2			2						58	84
	Bristlecone Pine					6													6	100
	BristleconePine/ Limber Pine						3											1	4	75
	Developed							1											1	100
	Gambel Oak											1							1	0
	Mohave Shrubland									2									2	100
	Mountain Shrubland		1	1			1	1	2	1	14			2				1	24	58
	Mountain Mahogany Mix											4		2				1	7	57
	Pinyon-Juniper/ Desert Shrub				2					1			15	9		1			28	54
	Pinyon-Juniper/ Montane Shrub				1					1	4	6	12	51	1	1			77	66
	Ponderosa Pine						1					1							2	0
	Rock Outcrop Shrubland																		0	N/A
	Upland Herbaceous		1	2															3	N/A
	White fir/ Ponderosa Pine						3							1	2			9	15	60
	Total	0	4	8	52	6	8	2	2	7	18	12	29	65	3	2	0	12	230	67
	Producer's Percent Accuracy	N/A	25	0	94	100	38	50	0	29	78	33	52	78	0	0	N/A	75	67	

Tree Size Class Error Matrix and Accuracies

The Forest Size Class 3 (21"+ DBH) had the best producer's accuracy of the classes (excluding Nonforest) at 67 percent (**Table 24**). Most of the confusion was within the Forest and Woodland classes, demonstrating that the mapping methods successfully separated Woodland from Forest. In general, more inventory plots were classified into a larger size class than the map classes. Forest and woodland size classes have historically been difficult to classify using spectral and terrain-based modeling techniques. Size class is a measure of tree diameter at breast height (DBH) and woodland diameter at root collar (DRC). Neither of these two variables is visible in the imagery from above, therefore class separation relies heavily upon shared spectral characteristics of similarly sized classes.

Table 24: Error matrix showing user's and producer's percent accuracies by tree size class on the SMNRA.

		INVENTORY PLOTS								
Size Class		Forest (0 -8.9" DBH)	Forest (9 - 20.9" DBH)	Forest (21"+ DBH)	Non Forest	Woodland (0 - 11.9" DRC)	Woodland (12 - 17.9" DRC)	Woodland (18"+ DRC)	Total	User's Percent Accuracy
MAP CLASS	Forest (0 -8.9" dbh)	1	1			1			3	33
	Forest (9 - 20.9" dbh)	1	7	2				1	11	64
	Forest (21"+ dbh)	2	5	6					13	46
	Non Forest	1	1		82	4	2		90	91
	Woodland (0 - 11.9" drc)	1			3	10	5	4	23	43
	Woodland (12 - 17.9" drc)				3	16	7	11	37	19
	Woodland (18"+ drc)			1	5	27	7	13	53	25
	Total	6	14	9	93	58	21	29	230	55
	Producer's Percent Accuracy	17	50	67	88	17	33	45	55	

Canopy Cover Class Error Matrix and Accuracies

The error matrix for canopy cover percentage indicates mixed results (**Table 25**). The highest producer's accuracy for any of the classes was the Tree Canopy Class 1 (TCC 10–20 percent) at 55 percent, followed by Tree Canopy Class 2 (TCC 21–40 percent) at 53 percent. In general, there was more confusion within the shrub and tree classes; however, there was still some confusion between tree and shrub classes. The general trend shows that the mapping effort had higher canopy cover percentages than the inventory field plots. Prior assessments have shown that shrub cover classes are harder to map than tree cover classes.

Table 25: Error matrix showing user's and producer's percent accuracies by canopy cover class on the SMNRA.

		INVENTORY PLOTS								Total	User's Percent Accuracy
Canopy Class		No canopy cover	SCC 10 - 20%	SCC 21 - 30%	SCC >= 31%	TCC 10 - 20%	TCC 21 - 40%	TCC 41 - 70%	TCC >= 71%		
MAP CLASS	No canopy cover	6								6	100
	SCC 10 - 20%	4	4	3	3					14	29
	SCC 21 - 30%	3	13	7	15	3	1			42	17
	SCC >= 31%	1	4	7	12	4				28	43
	TCC 10 - 20%		2	6	1	22	27	1		59	37
	TCC 21 - 40%			1	1	7	34	23		66	52
	TCC 41 - 70%					4	2	9		15	60
	TCC >= 71%								0	0	N/A
	Total	14	23	24	32	40	64	33	0	230	41
	Producer's Percent Accuracy	43	17	29	38	55	53	27	N/A	41	

Conclusions for Accuracy Assessment

Since its inception in the early 1980s, thematic accuracy assessment of remote sensing data has consistently been a particularly challenging portion of the mapping process. Despite its critical importance, there are a wide variety of data types and methods that can be used to attain relatively similar goals. Although a number of definitive standards have been adopted throughout the remote sensing community over the years, there still remains a great degree of uncertainty to the question of how best to perform a reliable, repeatable, and realistic accuracy assessment.

Although optimum reference datasets for accuracy assessment would be designed specifically for use with the final map product, this is often very cost prohibitive and time-consuming. The use of inventory data, such as FIA, involves trade-offs between resolution and reliability. FIA data provide a statistically robust, spatially distributed, unbiased sample that is readily available as a source of information that can serve as a base-level accuracy assessment for mid-level mapping. When used for accuracy assessments, consideration should be given to address differences in data collection methods compared with the map products.

Data Management

Polygon and Layer File Locations

The existing vegetation 'unioned' polygon feature class and its Federal Geographic Data Committee (FGDC)-compliant metadata are stored and maintained in ESRI geodatabase format within individual forest ArcSDE (Spatial Database Engine) schemas at the Forest Service Enterprise Data Center. This feature class serves as the authoritative source data. It is recommended that the data be accessed by Forest Service users through Citrix using ESRI ArcGIS software applications (<https://apps.fs.usda.gov/Citrix/auth/login.aspx>) to optimize performance. ArcGIS layer files (*.lyr) containing polygon-feature symbology for vegetation type, tree size, and canopy cover can be accessed from ArcGIS applications through Citrix at T:\FS\Reference\GIS\r04 htf\LayerFile\Vegetation\VegExistingMidLevelISMNRA2013.

More information on procedures used for accessing geospatial data through Citrix at the Data Center can be found at: http://fsweb.egis.fs.fed.us/EGIS_tools/GettingStartedEDC.shtml.

Ancillary and Intermediate Data

All other data related to this project, including ancillary and intermediate geospatial data, reference site information, and supporting documentation are stored and archived as the trusted source data set on the Intermountain Regional Office local Network Attached Storage (NAS) device and tape backup system. Assistance in accessing the authoritative source data through Citrix or obtaining a copy of ancillary and intermediate data sets may be facilitated by Regional Office project partners.

Conclusion

The status and condition of existing vegetation on the SMNRA is a critical factor for many of its land-management decisions. When used in conjunction with the associated maps, taxonomic keys, data, and map unit descriptions, this document provides the foundation for supporting applicable land management decisions using the best-available science. Since these products reflect a single point in time, specifically 2013 conditions, land managers should develop a strategy for maintaining their initial investment in the future. Maintenance and future updates will keep the vegetation map current and useful as vegetation disturbances, treatments, or gradual changes occur over time.

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Appendices

Appendix I: Acquired Geospatial Data for Mapping

Geospatial Data	Source	Use
Landsat 5 TM – September, 2010	USGS GloVis	Modeling
Landsat 8 OLI - April, 2013	USGS GloVis	Modeling
Landsat 8 OLI – May, 2013	USGS GloVis	Modeling
Landsat 8 OLI – June, 2013	USGS GloVis	Modeling
WorldView-2	Satellite Imaging Corp.	Modeling & Segmentation
NAIP	USDA FSA	Photo interpretation
Digital Elevation Model (DEM)	i-cubed DataDoors	Modeling & Segmentation
Administrative boundary	SMNRA	Identify project area
Land ownership	SMNRA	Field site selection
Roads & trails	SMNRA	Field site selection
Hydrology	SMNRA	Field site selection
gSSURGO soil data	USDA NRCS	Modeling
IfSAR	Intermap Technologies	Size class modeling
Fire severity & burn perimeters	MTBS	Modeling
Climate – average temperature	Daymet	Modeling
Climate – cooling degree days	Daymet	Modeling
Climate – frost days	Daymet	Modeling
Climate – growing days	Daymet	Modeling
Climate – heating degree days	Daymet	Modeling
Climate – total precipitation	Daymet	Modeling
Climate – max temperature	Daymet	Modeling
Climate – min temperature	Daymet	Modeling

Appendix II: Vegetation Indices, Transformations, and Topographic Derivatives

Geospatial Data	Source	Use
Landsat5 TM – Sept 2010 - NDVI	Erdas model	Modeling
Landsat5 TM – Sept 2010 – Principal Components (3)	Erdas model	Modeling
Landsat5 TM – Sept 2010 – Tasseled Cap	Erdas model	Modeling
Landsat8 OLI – April 2013 - NDVI	Erdas model	Modeling
Landsat8 OLI – April 2013 - Principal Components (3)	Erdas model	Modeling & Segmentation
Landsat8 OLI – April 2013 Tasseled Cap	Erdas model	Modeling
Landsat8 OLI – May 2013 – NDVI	Erdas model	Modeling
Landsat8 OLI – May 2013 - Principal Components (3)	Erdas model	Modeling
Landsat8 OLI – May 2013 – Tasseled Cap	Erdas model	Modeling
Landsat8 OLI – June 2013 – NDVI	Erdas model	Modeling
Landsat8 OLI – June 2013 - Principal Components (3)	Erdas model	Modeling
Landsat8 OLI – June 2013 – Tasseled Cap	Erdas model	Modeling
Landsat – Time series	Customized model	Modeling
WorldView-2 – NDVI	Erdas model	Modeling
WorldView-2 – Principal Components (3)	Erdas model	Modeling & Segmentation
Slope (degrees)	Customized model	Modeling
Slope-Aspect (Cos)	Customized model	Modeling & Segmentation
Slope-Aspect (Sin)	Customized model	Modeling & Segmentation
Slope position	Customized model	Modeling
Surface-ground ratio	Customized model	Modeling
Heatload	Customized model	Modeling
Hillshade	Customized model	Modeling

Appendix III: Existing Vegetation Keys

Spring Mountains NRA DRAFT Vegetation Keys

4/1/2015

Dave Tart, Jim Hurja, Jennifer Brickey, Jenny Hansen, Marisa Anderson

NOTE: These keys apply only to existing vegetation for mid-level mapping, not potential or historical vegetation.

R4 Key to Vegetation Formations

This key does not apply to lands used for agriculture or urban/residential development. It applies only to natural and semi-natural vegetation dominated by vascular plants. Semi-natural vegetation includes planted vegetation that is not actively managed or cultivated.

All cover values in this key to formations are absolute cover, not relative cover, for the life form. See Appendix A for a discussion of absolute versus relative cover. In this key, tree cover includes both regeneration and overstory sized trees, so that young stands of trees are classified as forest.

First, identify the R4 Vegetation Formation of the plot, stand, or polygon using the key below. Vegetation Type Map Units (Map Unit) are defined in Appendix B.

		Key or D.T.	Map Unit
1a	All vascular plants total < 1% canopy cover.....	Non-Vegetated (p.14)	
1b	All vascular plants total ≥ 1% canopy cover.....	2	
2a	All vascular plants total < 10% canopy cover.....	Sparse Veg.	BR/SV
2b	All vascular plants total ≥ 10% canopy cover.....	3	
3a	Trees total ≥ 10% canopy cover.....	4	
3b	Trees total < 10% canopy cover.....	5	
4a	Stand located above continuous forest line and trees stunted (< 5m tall) by harsh alpine growing conditions.....	Shrubland Key (p.8)	
4b	Stand not above continuous forest line; trees not stunted.....	Forest Key (p.2)	
5a	Shrubs total ≥ 10% canopy cover.....	Shrubland Key (p.8)	
5b	Shrubs total < 10% canopy cover.....	6	
6a	Herbaceous vascular plants total ≥ 10% canopy cover.....	7	
6b	Herbaceous vascular plants total < 10% canopy cover.....	8	
7a	Total cover of graminoids ≥ total cover of forbs.....	Grassland Key (p.12)	
7b	Total cover of graminoids < total cover of forbs.....	Forbland Key (p.13)	
8a	Trees total ≥ 5% canopy cover.....	Sparse Tree	BR/SV
8b	Trees total < 5% canopy cover.....	9	
9a	Shrubs total ≥ 5% canopy cover.....	Sparse Shrub	BR/SV
9b	Shrubs total < 5% canopy cover.....	10	
10a	Herbaceous vascular plants total ≥ 5% canopy cover.....	Sparse Herb	BR/SV
10b	Herbaceous vascular plants total < 5% canopy cover.....	Sparse Veg.	BR/SV

Key to Forest and Woodland Dominance Types and DT Phases

Instructions:

1. Preferably, plots or polygons should be keyed out based on overstory canopy cover (trees forming the upper or uppermost canopy layer) by tree species.
2. Plots or polygons lacking such data or lacking an overstory layer should be keyed out using total cover by species.
3. If a plot or polygon does not key out using overstory cover, then it may be keyed using total tree cover.
4. If two trees are equally abundant, the species encountered first in the key is recorded as the most abundant.
5. If a tree species is not listed, then consult with the Regional Ecologist to assign a dominance type and map unit.

		DT or DT Phase Code	Map Unit	Map Group
1a	Narrowleaf cottonwood is the most abundant tree species.....	POAN3 d.t.	RV	R
1b	Narrowleaf cottonwood is not the most abundant tree species.....	2		
2a	Fremont cottonwood is the most abundant tree species.....	POFR2 d.t.	RV	R
2b	Fremont cottonwood is not the most abundant tree species.....	3		
3a	Water birch is the most abundant tree species.....	BEOC2 d.t.	RV	R
3b	Water birch is not the most abundant tree species.....	4		
4a	Desert willow is the most abundant tree species.....	CHLI2 d.t.	RV	R
4b	Desert willow is not the most abundant tree species.....	5		
5a	Velvet ash is the most abundant tree species.....	FRVE2 d.t.	RV	R
5b	Velvet ash is not the most abundant tree species.....	6		
6a	Saltcedar is the most abundant tree species.....	TARA d.t.	RV	R
6b	Saltcedar is not the most abundant tree species.....	7		
7a	Quaking aspen is the most abundant tree species.....	8		
7b	Quaking aspen is not the most abundant tree species.....	12		
8a	Quaking aspen ≥ 80% relative canopy cover.....	POTR5-POTR5 d.t.p.	AS	D
8b	Quaking aspen < 80% relative canopy cover	9		
9a	Bristlecone pine and/or limber pine total ≥ 40% relative canopy cover, together or separately.....	POTR5-PILO d.t.p.	AS	D
9b	Bristlecone pine and limber pine total < 40% relative canopy	10		
10a	Ponderosa pine is the second most abundant tree species; it and aspen total ≥ 60% relative canopy	POTR5-PIPO d.t.p.	AS	D
10b	Ponderosa pine is not the second most abundant tree species and/or it and aspen total < 60% relative canopy	11		
11a	White fir is the second most abundant tree species; it and aspen total ≥ 60% relative canopy	POTR5-ABCO d.t.p.	AS	D
11b	White fir is not the second most abundant tree species and/or it and aspen total < 60% relative canopy	POTR5 d.t.	AS	D
12a	Bristlecone pine is the most abundant tree species.....	13		
12b	Bristlecone pine is not the most abundant tree species.....	17		
13a	Bristlecone pine ≥ 80% relative canopy cover.....	PILO-PILO d.t.p.	BCP	C
13b	Bristlecone pine < 80% relative canopy cover	14		
14a	Limber pine is the second most abundant tree species; it and bristlecone pine total ≥ 60% relative canopy	PILO-PIFL2 d.t.p.	BC/LM	C
14b	Limber pine is not the second most abundant tree species and/or it and bristlecone pine total < 60% relative canopy.....	15		

		DT or DT Phase Code	Map Unit	Map Group
15a	Ponderosa pine is the second most abundant tree species; it and bristlecone pine total $\geq 60\%$ relative canopy	PILO-PIPO d.t.p.	BC/LM	C
15b	Ponderosa pine is not the second most abundant tree species and/or it and bristlecone pine total $< 60\%$ relative canopy.....	16		
16a	White fir is the second most abundant tree species; it and bristlecone pine total $\geq 60\%$ relative canopy	PILO-ABCO d.t.p.	BC/LM	C
16b	White fir is not the second most abundant tree species and/or it and bristlecone pine total $< 60\%$ relative canopy	PILO d.t.	BC/LM	C
17a	Limber pine is the most abundant tree species.....	18		
17b	Limber pine is not the most abundant tree species.....	21		
18a	Limber pine $\geq 80\%$ relative canopy cover.....	PIFL2-PIFL2 d.t.p.	BC/LM	C
18b	Limber pine $< 80\%$ relative canopy cover	19		
19a	Bristlecone pine is the second most abundant tree species; it and limber pine total $\geq 60\%$ relative canopy.....	PIFL2-PILO d.t.p	BC/LM	C
19b	Bristlecone pine is not the second most abundant tree species and/or it and limber pine total $< 60\%$ relative canopy.....	20		
20a	White fir is the second most abundant tree species; it and limber pine total $\geq 60\%$ relative canopy cover.....	PIFL2-ABCO d.t.p.	BC/LM	C
20b	White fir is not the second most abundant tree species and/or it and limber pine total $< 60\%$ relative canopy cover.....	PIFL2 d.t.	BC/LM	C
21a	Ponderosa pine is the most abundant tree species.....	22		
21b	Ponderosa pine is not the most abundant tree species.....	31		
22a	Bristlecone pine and/or limber pine total $\geq 40\%$ relative canopy cover, together or separately.....	23		
22b	Bristlecone pine and limber pine total $< 40\%$ relative canopy	24		
23a	Bristlecone pine is more abundant than limber pine.....	PIPO-PILO d.t.p.	BC/LM	C
23b	Bristlecone pine is less abundant than limber pine.....	PIPO-PIFL2 d.t.p.	BC/LM	C
24a	Ponderosa pine $\geq 80\%$ relative canopy cover.....	PIPO-PIPO d.t.p.	PP	C
24b	Ponderosa pine $< 80\%$ relative canopy cover	25		
25a	White fir is the second most abundant tree species; it and ponderosa pine total $\geq 60\%$ relative canopy cover.....	PIPO-ABCO d.t.p.	WF/PP	C
25b	White fir is not the second most abundant tree species and/or it and ponderosa pine total $< 60\%$ relative canopy cover.....	26		
26a	Curlleaf mountain mahogany is the second most abundant tree species; it and ponderosa pine total $\geq 60\%$ relative canopy cover.....	PIPO-CELE3 d.t.p	PP	C
26b	Curlleaf mountain mahogany is not the second most abundant tree species and/or it and ponderosa pine total $< 60\%$ relative canopy cover.....	27		
27a	Rocky Mountain juniper is the second most abundant tree species; it and ponderosa pine total $\geq 60\%$ relative canopy cover.....	PIPO-JUSC2 d.t.p.	PP	C
27b	Rocky Mountain juniper is not the second most abundant tree species and/or it and ponderosa pine total $< 60\%$ relative canopy cover.....	28		
28a	Singleleaf pinyon is the second most abundant tree species; it and ponderosa pine total $\geq 60\%$ relative canopy	PIPO-PIMO d.t.p.	PP	C
28b	Singleleaf pinyon is not the second most abundant tree species and/or it and ponderosa pine total $< 60\%$ relative canopy	29		

		DT or DT Phase Code	Map Unit	Map Group
29a	Utah juniper is the second most abundant tree species; it and ponderosa pine total $\geq 60\%$ relative canopy cover.....	PIPO-JUOS d.t.p.	PP	C
29b	Utah juniper is not the second most abundant tree species and/or it and ponderosa pine total $< 60\%$ relative canopy cover.....	30		
30a	Gamble oak is the second most abundant tree species; it and ponderosa pine total $\geq 60\%$ relative canopy cover.....	PIPO-QUGA d.t.p.	PP	C
30b	Gamble oak is not the second most abundant tree species and/or it and ponderosa pine total $< 60\%$ relative canopy cover.....	PIPO d.t.	PP	C
31a	White fir is the most abundant tree species.....	32		
31b	White fir is not the most abundant tree species.....	42		
32a	Bristlecone pine and/or limber pine total $\geq 40\%$ relative canopy cover, together or separately.....	33		
32b	Bristlecone pine and limber pine total $< 40\%$ relative canopy	34		
33a	Bristlecone pine more abundant than limber pine.....	ABCO-PILO d.t.p.	BC/LM	C
33b	Bristlecone pine less abundant than limber pine.....	ABCO-PIFL2 d.t.p.	BC/LM	C
34a	White fir $\geq 80\%$ relative canopy cover.....	ABCO-ABCO d.t.p.	WF/PP	C
34b	White fir $< 80\%$ relative canopy cover	35		
35a	Bristlecone pine is the second most abundant tree species; it and white fir total $\geq 60\%$ relative canopy cover.....	ABCO-PILO d.t.p.	BC/LM	C
35b	Bristlecone pine is not the second most abundant tree species and/or it and white fir total $< 60\%$ relative canopy.....	36		
36a	Limber pine is the second most abundant tree species; it and white fir total $\geq 60\%$ relative canopy cover.....	ABCO-PIFL2 d.t.p.	BC/LM	C
36b	Limber pine is not the second most abundant tree species and/or it and white fir total $< 60\%$ relative canopy.....	37		
37a	Aspen is the second most abundant tree species; it and white fir total $\geq 60\%$ relative canopy	ABCO-POTR5 d.t.p.	WF/PP	C
37b	Aspen is not the second most abundant tree species and/or it and white fir total $< 60\%$ relative canopy	38		
38a	Ponderosa pine is the second most abundant tree species; it and white fir total $\geq 60\%$ relative canopy	ABCO-PIPO d.t.p.	WF/PP	C
38b	Ponderosa pine is not the second most abundant tree species and/or it and white fir total $< 60\%$ relative canopy	39		
39a	Curlleaf mountain mahogany is the second most abundant tree species; it and white fir total $\geq 60\%$ relative canopy cover.....	ABCO-CELE3 d.t.p.	WF/PP	C
39b	Curlleaf mountain mahogany is not the second most abundant tree species and/or it and white fir total $< 60\%$ relative canopy cover.....	40		
40a	Rocky Mountain juniper is the second most abundant tree species; it and white fir total $\geq 60\%$ relative canopy cover.....	ABCO-JUSC2 d.t.p.	WF/PP	C
40b	Rocky Mountain juniper is not the second most abundant tree species and/or it and white fir total $< 60\%$ relative canopy cover.....	41		
41a	Singleleaf pinyon is the second most abundant tree species; it and white fir total $\geq 60\%$ relative canopy	ABCO-PIMO d.t.p.	WF/PP	C
41b	Singleleaf pinyon is not the second most abundant tree species and/or it and white fir total $< 60\%$ relative canopy	ABCO d.t.	WF/PP	C
42a	Curlleaf mountain mahogany is the most abundant tree species.....	43		
42b	Curlleaf mountain mahogany is not the most abundant tree			

		DT or DT Phase Code	Map Unit	Map Group
species.....		53		
43a	Bristlecone pine and/or limber pine total ≥ 40% relative canopy cover, together or separately.....	CELE3-PILO d.t.p.	BC/LM	C
43b	Bristlecone pine and limber pine total < 40% relative canopy	44		
44a	Curleaf mountain mahogany ≥ 80% relative canopy cover.....	CELE3-CELE3 d.t.p.	MMmix	W
44b	Curleaf mountain mahogany < 80% relative canopy cover	45		
45a	Bristlecone pine is the second most abundant tree species; it and curleaf mountain mahogany ≥ 60% relative canopy.....	CELE3-PILO d.t.p	BC/LM	C
45b	Bristlecone pine is not the second most abundant tree species and/or it and curleaf mountain mahogany total < 60% relative canopy.....	46		
46a	Limber pine is the second most abundant tree species; it and curleaf mountain mahogany ≥ 60% relative canopy.....	CELE3-PIFL2 d.t.p.	BC/LM	C
46b	Limber pine is not the second most abundant tree species and/or it and curleaf mountain mahogany total < 60% relative canopy.....	47		
47a	Ponderosa pine is the second most abundant tree species; it and curleaf mountain mahogany ≥ 60% relative canopy	CELE3-PIPO d.t.p.	PP	C
47b	Ponderosa pine is not the second most abundant tree species and/or it and curleaf mountain mahogany total < 60% relative canopy	48		
48a	White fir is the second most abundant tree species; it and curleaf mountain mahogany total ≥ 60% relative canopy cover.....	CELE3-ABCO d.t.p.	WF/PP	C
48b	White fir is not the second most abundant tree species and/or it and curleaf mountain mahogany total < 60% relative canopy cover.....	49		
49a	Rocky Mountain juniper is the second most abundant tree species; it and curleaf mountain mahogany total ≥ 60% relative canopy cover.....	CELE3-JUSC2 d.t.p.	MMmix	W
49b	Rocky Mountain juniper is not the second most abundant tree species and/or it and curleaf mountain mahogany total < 60% relative canopy cover.....	50		
50a	Singleleaf pinyon is the second most abundant tree species; it and curleaf mountain mahogany total ≥ 60% relative canopy	CELE3-PIMO d.t.p.	MMmix	W
50b	Singleleaf pinyon is not the second most abundant tree species and/or it and curleaf mountain mahogany total < 60% relative canopy	51		
51a	Utah juniper is the second most abundant tree species; it and curleaf mountain mahogany total ≥ 60% relative canopy cover.....	CELE3-JUOS d.t.p.	MMmix	W
51b	Utah juniper is not the second most abundant tree species and/or it and curleaf mountain mahogany total < 60% relative canopy cover..	52		
52a	Gambel oak is the second most abundant tree species; it and curleaf mountain mahogany total ≥ 60% relative canopy cover.....	CELE3-QUGA d.t.p.	GO	W
52b	Gambel oak is not the second most abundant tree species and/or it and curleaf mountain mahogany total < 60% relative canopy cover..	CELE3 d.t.	MMmix	W
53a	Rocky Mountain juniper is the most abundant tree species.....	54		
53b	Rocky Mountain juniper is not the most abundant tree species.....	59		
54a	Bristlecone pine and/or limber pine total ≥ 40% relative canopy cover, together or separately.....	JUSC2-PILO d.t.p.	BC/LM	C
54b	Bristlecone pine and limber pine total < 40% relative canopy	55		
55a	Rocky Mountain juniper ≥ 80% relative canopy cover.....	JUSC2-JUSC2 d.t.p.	PJ/MT	W

		DT or DT Phase Code	Map Unit	Map Group
55b	Rocky Mountain juniper < 80% relative canopy cover	56		
56a	Ponderosa pine is the second most abundant tree species; it and Rocky Mountain juniper total ≥ 60% relative canopy cover	JUSC-PIPO d.t.p	PP	C
56b	Ponderosa pine is not the second most abundant tree species and/or it and Rocky Mountain juniper total < 60% relative canopy cover.....	57		
57a	Curleaf mountain mahogany is the second most abundant tree species; it and Rocky Mountain juniper total ≥ 60% relative canopy cover.....	JUSC2-CELE3 d.t.p.	MMmix	W
57b	Curleaf mountain mahogany is not the second most abundant tree species and/or it and Rocky Mountain juniper total < 60% relative canopy cover.....	58		
58a	Singleleaf pinyon is the second most abundant tree species; it and Rocky Mountain juniper total ≥ 60% relative canopy cover.....	JUSC2-PIMO d.t.p.	Go to 77	W
58b	Singleleaf pinyon is not the second most abundant tree species and/or it and Rocky Mountain juniper total < 60% relative canopy cover.....	JUSC2 d.t.	Go to 77	W
59a	Utah juniper is the most abundant tree species.....	60		
59b	Utah juniper is not the most abundant tree species.....	63		
60a	Utah juniper ≥ 75% relative canopy cover.....	JUOS-JUOS d.t.p	Go to 77	W
60b	Utah juniper < 75% relative canopy cover	61		
61a	Curleaf mountain mahogany is the second most abundant tree species; it and Utah juniper ≥ 60% relative canopy cover.....	JUOS-CELE3 d.t.p.	Go to 77	W
61b	Curleaf mountain mahogany is not the second most abundant tree species and/or it and Utah juniper total < 60% relative canopy cover.....	62		
62a	Singleleaf pinyon is the second most abundant tree species; it and Utah juniper total ≥ 60% relative canopy cover.....	JUOS-PIMO d.t.p.	Go to 77	W
62b	Singleleaf pinyon is not the second most abundant tree species and/or it and Utah juniper total < 60% relative canopy cover.....	JUOS d.t.	Go to 77	W
63a	Singleleaf pinyon is the most abundant tree species.....	64		
63b	Singleleaf pinyon is not the most abundant tree species.....	71		
64a	Singleleaf pinyon ≥ 80% relative canopy cover.....	PIMO-PIMO d.t.p.	Go to 77	W
64b	Singleleaf pinyon < 80% relative canopy cover	65		
65a	Ponderosa pine is the second most abundant tree species; it and singleleaf pinyon ≥ 60% relative canopy	PIMO-PIPO d.t.p.	Go to 77	W
65b	Ponderosa pine is not the second most abundant tree species and/or it and singleleaf pinyon total < 60% relative canopy	66		
66a	White fir is the second most abundant tree species; it and singleleaf pinyon total ≥ 60% relative canopy cover.....	PIMO-ABCO d.t.p.	Go to 77	W
66b	White fir is not the second most abundant tree species and/or it and singleleaf pinyon total < 60% relative canopy cover.....	67		
67a	Curleaf mountain mahogany is the second most abundant tree species; it and singleleaf pinyon total ≥ 60% relative canopy cover.....	PIMO-CELE3 d.t.p.	MMmix	W
67b	Curleaf mountain mahogany is not the second most abundant tree species and/or it and singleleaf pinyon total < 60% relative canopy cover.....	68		

		DT or DT Phase Code	Map Unit	Map Group
68a	Rocky Mountain juniper is the second most abundant tree species; it and singleleaf pinyon total ≥ 60% relative canopy cover.....	PIMO-JUSC2 d.t.p.	PJ/MT	W
68b	Rocky Mountain juniper is not the second most abundant tree species and/or it and singleleaf pinyon total < 60% relative canopy cover.....	69		
69a	Utah juniper is the second most abundant tree species; it and singleleaf pinyon total ≥ 60% relative canopy cover.....	PIMO-JUOS d.t.p.	Go to 77	W
69b	Utah juniper is not the second most abundant tree species and/or it and singleleaf pinyon total < 60% relative canopy cover.....	70		
70a	Gambel oak is the second most abundant tree species; it and singleleaf pinyon total ≥ 60% relative canopy cover.....	PIMO-QUGA d.t.p.	GO	W
70b	Gambel oak is not the second most abundant tree species and/or it and singleleaf pinyon total < 60% relative canopy cover.....	PIMO d.t.	Go to 77	W
71a	Gambel oak is the most abundant tree species.....	72		
71b	Gambel oak is not the most abundant tree species.....	74		
72a	Gambel oak ≥ 80% relative canopy cover.....	QUGA-QUGA d.t.p.	GO	W
72b	Gambel oak < 80% relative canopy cover.....	73		
73a	Singleleaf pinyon is the second most abundant tree species; it and Gambel oak total ≥ 60% relative canopy cover.....	QUGA-PIMO d.t.p.	GO	W
73b	Singleleaf pinyon is not the second most abundant tree species and/or it and Gambel oak total < 60% relative canopy cover.....	QUGA d.t.	GO	W
74a	Joshua tree is the most abundant tree species.....	YUBR d.t.	BBSH	S
74b	Joshua tree is not the most abundant tree species.....	75		
75a	Honey mesquite is the most abundant tree species.....	PRGLT d.t.	RV	R
75b	Honey mesquite is not the most abundant tree species.....	76		
76a	Screwbean mesquite is the most abundant tree species.....	PRPU d.t.	RV	R
76b	Screwbean mesquite is not the most abundant tree species.....	Undefined d.t		
77a	Curlleaf mountain mahogany or Gambel oak present.....		PJ/MT	W
77b	Curlleaf mountain mahogany and Gambel oak both absent.....		78	
78a	Total cover of desert shrubs ≥ total cover of montane shrubs (listed below).....		PJ/DE	W
78b	Total cover of montane shrubs ≥ total cover of desert shrubs (listed below).....		PJ/MT	W
78c	No desert or montane shrubs present.....		79	
79a	Elevation ≥ 7000 feet.....		PJ/MT	W
79b	Elevation < 7000 feet.....		PJ/DE	W
Desert Shrubs (DE)		Montane Shrubs (MT)		
<i>Agave utahensis</i> <i>Artemisia tridentata</i> ssp. <i>tridentata</i> <i>Coleogyne ramosissima</i> <i>Echinocereus engelmannii</i> <i>Ephedra nevadensis</i> <i>Ericameria linearifolia</i> <i>Eriodictyon angustifolium</i> <i>Escobaria vivipara</i>		<i>Fallugia paradoxa</i> <i>Glossopetalon spinescens</i> <i>Menodora spinescens</i> <i>Opuntia basilaris</i> <i>Prunus andersonii</i> <i>Prunus fasciculata</i> <i>Thamnosia montana</i> <i>Yucca baccata</i>		
		<i>Acer glabrum</i> <i>Amelanchier utahensis</i> <i>Arctostaphylos pungens</i> <i>Artemisia tridentata</i> ssp. <i>vaseyana</i> <i>Berberis repens</i> <i>Ceanothus greggii</i> <i>Garrya flavescens</i> <i>Holodiscus discolor</i> <i>Opuntia phaeacantha</i>		
		<i>Peraphyllum ramosissimum</i> <i>Ribes cereum</i> <i>Ribes roezlii</i> <i>Ribes velutinum</i> <i>Symphoricarpos longiflorus</i> <i>Symphoricarpos</i> <i>Symphoricarpos oreophilus</i> <i>Tetradymia canescens</i>		

Key to Shrubland Dominance Types

Instructions:

Plots or polygons should be keyed out based on total cover by species. This key is divided into riparian, alpine, and upland sections. First, identify the physical setting of the plot, stand, or polygon using the key below.

For the purposes of this key, a riparian setting is defined as an area (typically transitional between aquatic and terrestrial ecosystems) identified by soil characteristics associated with at least seasonally high water tables, distinctive vegetation that requires or tolerates free or unbound water (Manning and Padgett 1995), proximity to a stream or lake, and/or topographic position (e.g., valley bottom). The alpine setting includes the area above the upper limit of continuous forest. Above this limit, trees occur only in scattered patches and become increasingly stunted at higher elevations (Arno and Hammerly 1984). In this key, the alpine setting takes precedence over the riparian setting. The upland setting includes non-riparian areas below the continuous forest line.

It is likely that some dominance types occur in more than one of these settings. If your plot does not key out successfully in one setting, then try another setting.

Key to Physical Habitat Setting

Key Leads:

- | | | |
|----|--|---------------------------------|
| 1a | Stand is located in an alpine setting above the upper elevation limit of continuous forest..... | Go to Alpine Key (p.8) |
| 1b | Stand is located below the upper elevation limit of continuous forest..... | 2 |
| 2a | Stand is located in a riparian setting as indicated by proximity to a stream or lake, topographic position, plant species that require or tolerate free or unbound water, and/or soil properties associated with seasonally high water tables..... | Go to Riparian Key (p.9) |
| 2b | Stand not located in a riparian setting as described above..... | Go to Upland Key (p.10) |

Key to Alpine Shrubland Dominance Types

Instructions:

1. Codes for dominance type and map unit can be found using Table 1. Find the name of the most abundant shrub in column 2 and move to column 3 for the dominance type code, column 4 for the map unit code, and column 5 for the map group code.
2. When two or more shrub species are equal in abundance, the species listed first in Table 1 is used to assign the dominance type and map unit.
3. If the most abundant shrub species is not listed in Table 1, then consult with the Regional Ecologist to assign a dominance type.

Table 1: Most Abundant Alpine Shrub and Indicated Dominance Type and Map Unit

(1) Rank	(2) Most Abundant Shrub (Dominance Type)		(3) Dom. Type Code	(4) Map Unit Code	(5) Map Group
1	<i>Ribes montigenum</i>	gooseberry currant	RIMO2	ALP	A
2	<i>Juniperus communis</i>	Common juniper	JUCO6	ALP	A
	Species not listed above		See Instruction 3 above	ALP	A
	Species unidentifiable		UNKNOWN	ALP	A

Key to Riparian Shrubland Dominance Types

Instructions:

1. Plots or polygons should be keyed out based on total cover by species.
2. Codes for dominance type and map unit can be found using Table 2. Find the name of the most abundant shrub in column 2 and move to column 3 for the dominance type code, column 4 for the map unit code, and column 5 for the map group code.
3. When two or more shrub species are equal in abundance, the species listed first in Table 2 is used to assign the dominance type and map unit.
4. If the most abundant shrub species is not listed in Table 2, then consult with the Regional Ecologist to assign a dominance type.

Table 2: Most Abundant Riparian Shrub and Indicated Dominance Type and Map Unit

(1) Rank	(2) Most Abundant Shrub (Dominance Type)		(3) Dom. Type Code	(4) Map Unit Code	(5) Map Group
1	<i>Betula occidentalis</i>	water birch	BEOC2	RV	R
2	<i>Salix lasiolepis</i>	arroyo willow	SALA6	RV	R
3	<i>Salix exigua</i>	coyote willow	SAEX	RV	R
4	<i>Rhus trilobata</i>	skunkbrush sumac	RHTR	RV	R
5	<i>Rosa woodsii</i>	Woods' rose	ROWO	RV	R
6	<i>Baccharis sergiloides</i>	desert baccharis	BASE	RV	R
7	<i>Vitis arizonica</i>	canyon grape	VIAR2	RV	R
8	<i>Tamarix ramosissima</i>	saltcedar	TARA	RV	R
9	<i>Prosopis pubescens</i>	screwbean mesquite	PRPU	RV	R
10	<i>Prosopis glandulosa</i>	Honey mesquite	PRGLT	RV	R
11	<i>Lepidospartum latisquatum</i>	Nevada broomsage	LELA4	See Table 3a	S
	Species not listed above		See Instruction 4 above	RV	R
	Species unidentifiable		UNKNOWN	RV	R

Key to Upland Shrubland Dominance Types

Instructions:

1. Plots or polygons should be keyed out based on total cover by species.
2. Codes for dominance type and map unit can be found using Table 3. Find the name of the most abundant shrub in column 2 and move to column 3 for the dominance type code, column 4 for the map unit code, and column 5 for the map group code.
3. When two or more shrub species are equal in abundance, the species listed first in Table 3 is used to assign the dominance type and map unit.
4. If the most abundant shrub species is not listed in Table 3, then consult with the Regional Ecologist to assign a dominance type and map unit.

Table 3. Most Abundant Upland Shrub and Indicated Dominance Type and Map Unit.

(1) Rank	(2) Most Abundant Shrub (Dominance Type)		(3) Dom. Type Code	(4) Map Unit Code	(5) Map Group
1	<i>Acer glabrum</i>	Rocky Mountain maple	ACGL	MS	S
2	<i>Ribes montigenum</i>	gooseberry currant	RIMO2	MS	S
3	<i>Juniperus communis</i>	common juniper	JUCO6	MS	S
4	<i>Ribes viscosissimum</i>	sticky currant	RIVI3	MS	S
5	<i>Ribes cereum</i>	wax currant	RICE	MS	S
6	<i>Rosa woodsii</i>	Woods' rose	ROWO	MS	S
7	<i>Peraphyllum ramosissimum</i>	wild crab apple	PERA4	MS	S
8	<i>Ceanothus greggii</i>	desert ceanothus	CEGR	MS	S
9	<i>Garrya flavescens</i>	ashy silktassel	GAFL2	MS	S
10	<i>Ericameria linearifolia</i>	narrowleaf goldenbush	ERLI6	MS	S
11	<i>Arctostaphylos pungens</i>	Pointleaf manzanita	ARPU5	MS	S
12	<i>Artemisia tridentata</i> ssp. <i>vaseyana</i>	mountain big sagebrush	ARTRV	MS	S
13	<i>Jamesia americana</i>	fivepetal cliffbush	JAAM	ROSH	S
14	<i>Cercocarpus intricatus</i>	littleleaf mtn. mahogany	CEIN7	ROSH	S
15	<i>Mortonia utahensis</i>	Utah mortonia	MOUT	ROSH	S
16	<i>Brickellia atractyloides</i>	spearleaf brickellbush	BRAT	ROSH	S
17	<i>Buddleja utahensis</i>	Utah butterflybush	BUUT	ROSH	S
18	<i>Peucephyllum schottii</i>	Schott's pygmycedar	PESC4	ROSH	S
19	<i>Petrophyton caespitosum</i>	mat rockspirea	PECA12	ROSH	S
20	<i>Fallugia paradoxa</i>	Apache plume	FAPA	BBSH	S
21	<i>Atriplex canescens</i>	fourwing saltbush	ATCA2	BBSH	S
22	<i>Glossopetalon spinescens</i>	spiny greasebush	GLSP	BBSH	S
23	<i>Coleogyne ramosissima</i>	blackbrush	CORA	BBSH	S
24	<i>Atriplex confertifolia</i>	shadscale saltbush	ATCO	BBSH	S
25	<i>Grayia spinosa</i>	spiny hopsage	GRSP	BBSH	S
26	<i>Krascheninnikovia lanata</i>	winterfat	KRLA2	BBSH	S
27	<i>Yucca baccata</i>	banana yucca	YUBA	BBSH	S
28	<i>Eriogonum fasciculatum</i>	East. Mojave buckwheat	ERFA2	BBSH	S
29	<i>Larrea tridentata</i>	creosote bush	LATR2	MOSH	S
30	<i>Ambrosia dumosa</i>	burrobush	AMDU2	MOSH	S
31	<i>Menodora spinescens</i>	spiny menodora	MESP2	MOSH	S
32	<i>Prunus fasciculata</i>	desert almond	PRFA	MOSH	S
33	<i>Salazaria mexicana</i>	Mexican bladdersage	SAME	MOSH	S
34	<i>Eriodictyon angustifolium</i>	narrowleaf yerba santa	ERAN2	MOSH	S
35	<i>Yucca schidigera</i>	Mojave yucca	YUSC2	MOSH	S
36	<i>Psorothamnus fremontii</i>	Fremont's dalea	PSFR	MOSH	S
37	<i>Lycium andersonii</i>	water jacket	LYAN	MOSH	S
38	<i>Hymenoclea salsola</i>	burrobush	HYSA	MOSH	S
39	<i>Encelia virginensis</i>	Virgin River brittlebush	ENVI	MOSH	S
40	<i>Ericameria teretifolia</i>	green rabbitbrush	ERTE18	MOSH	S
41	<i>Ericameria cuneata</i>	cliff goldenbush	ERCU7	MOSH	S

42	<i>Ephedra viridis</i>	Mormon tea	EPVI	See Table 3a	S
43	<i>Artemisia tridentata</i> ssp. <i>tridentata</i>	basin big sagebrush	ARTRT	See Table 3a	S
44	<i>Artemisia trid.</i> ssp. <i>wyomingensis</i>	Wyoming big sagebrush	ARTRW8	See Table 3a	S
45	<i>Chrysothamnus viscidiflorus</i>	yellow rabbitbrush	CHVI8	See Table 3a	S
46	<i>Ericameria nauseosa</i>	rubber rabbitbrush	ERNA10	See Table 3a	S
47	<i>Artemisia nova</i>	black sagebrush	ARNO4	See Table 3a	S
48	<i>Eriogonum microthecum</i>	slender buckwheat	ERMI4	See Table 3a	S
49	<i>Purshia stansburiana</i>	Stansbury cliffrose	PUST	See Table 3a	S
50	<i>Purshia glandulosa</i>	Desert bitterbrush	PUGL2	See Table 3a	S
51	<i>Salvia dorrii</i>	purple sage	SADO4	See Table 3a	S
52	<i>Gutierrezia microcephala</i>	threadleaf snakeweed	GUMI	See Table 3a	S
53	<i>Gutierrezia sarothrae</i>	broom snakeweed	GUSA2	See Table 3a	S
54	<i>Lepidospartum latisquatum</i>	Nevada broomsage	LELA4	See Table 3a	S
	Species not listed above		See Instruction 4 above		S
	Species unidentifiable		UNKNOWN		S

Table 3a. Most Abundant Shrub Group and Indicated Map Unit.

Instructions:

1. Sum the cover of the shrubs from each of the three groups below on your plot.
2. Assign the plots to the map unit indicated by the shrub group with the highest total cover.

Shrub Group:	Montane Shrubs	Blackbrush Associates	Mojave Shrubs
Map Unit:	MS	BBSH	MOSH
Species:	<i>Acer glabrum</i> <i>Amelanchier utahensis</i> <i>Arctostaphylos pungens</i> <i>Artemisia tridentata</i> ssp. <i>vaseyana</i> <i>Berberis repens</i> <i>Ceanothus greggii</i> <i>Ericameria linearifolia</i> <i>Eriodictyon angustifolium</i> <i>Garrya flavescens</i> <i>Holodiscus discolor</i> <i>Opuntia phaeacantha</i> <i>Peraphyllum ramosissimum</i> <i>Ribes cereum</i> <i>Ribes viscosissimum</i> <i>Rosa woodsii</i> <i>Symphoricarpos longiflorus</i> <i>Symphoricarpos oreophilus</i> <i>Tetradymia canescens</i>	<i>Atriplex canescens</i> <i>Atriplex confertifolia</i> <i>Coleogyne ramosissima</i> <i>Eriogonum fasciculatum</i> <i>Fallugia paradoxa</i> <i>Glossopetalon spinescens</i> <i>Grayia spinosa</i> <i>Krascheninnikovia lanata</i> <i>Yucca baccata</i>	<i>Ambrosia dumosa</i> <i>Encelia virginensis</i> <i>Ericameria teretifolia</i> <i>Ericameria cuneata</i> <i>Hymanoclea salsola</i> <i>Larrea tridentata</i> <i>Lycium andersonii</i> <i>Menodora spinescens</i> <i>Prunus fasciculata</i> <i>Psoralea fremontii</i> <i>Salazaria mexicana</i> <i>Yucca schidigera</i>

Key to Grassland Dominance Types

Plots or polygons should be keyed out based on total cover by species.

Instructions:

1. Codes for dominance type and map unit can be found using Table 4. Find the name of the most abundant species in column 2 and move to column 3 for the dominance type code, column 4 for the map unit code, and column 5 for the map group code.
2. When two or more species are equal in abundance, the species listed first in Table 4 is used to assign the dominance type and map unit.
3. If the most abundant species is not listed in Table 4, then consult with the Regional Ecologist to assign a dominance type and map unit.

Table 4: Most Abundant Graminoid and Indicated Dominance Type and Map Unit

(1) Rank	(2) Most Abundant Graminoid (Dominance Type)		(3) Dom. Type Code	(4) Map Unit Code	(5) Map Group
1	<i>Eleocharis rostellata</i>	beaked spikerush	ELRO2	RV	R
2	<i>Carex nebrascensis</i>	Nebraska sedge	CANE2	RV	R
3	<i>Juncus mexicana</i>	Mexican rush	JUME4	RV	R
4	<i>Juncus ensifolius</i>	swordlead rush	JUEN	RV	R
5	<i>Leymus triticoides</i>	beardless wildrye	LETR5	RV	R
6	<i>Juncus arcticus</i> ssp. <i>littoralis</i>	mountain rush	JUARL	RV	R
7	<i>Distichlis spicata</i>	saltgrass	DISP	RV	R
8	<i>Poa pratensis</i>	Kentucky bluegrass	POPR	RV	R
9	<i>Achnatherum lettermanii</i>	Letterman's needlegrass	ACLE9	ALP	A
10	<i>Leymus cinereus</i>	basin wildrye	LECI4	UHE	H
11	<i>Pleuraphis rigida</i>	big galleta	PLRI3	UHE	H
12	<i>Bromus inermis</i>	smooth brome	BRIN2	UHE	H
13	<i>Agropyron desertorum</i>	desert wheatgrass	AGDE2	UHE	H
14	<i>Bromus tectorum</i>	cheatgrass	BRTE	AHE	H
15	<i>Bromus rubens</i>	red brome	BRRU2	AHE	H
	Species not listed above		See Instruction 3 above		
	Species unidentifiable		UNKNOWN		

Key to Forbland Dominance Types

Plots or polygons should be keyed out based on total cover by species.

Instructions:

1. Codes for dominance type and map unit can be found using Table 5. Find the name of the most abundant forb in column 2 and move to column 3 for the dominance type code, column 4 for the map unit code, and column 5 for the map group code.
2. When two or more forb species are equal in abundance, the species listed first in Table 5 is used to assign the dominance type and map unit.
3. If the most abundant forb species is not listed in Table 5, then consult with the Regional Ecologist to assign a dominance type and map unit.

Table 5: Most Forb and Indicated Dominance Type and Map Unit

(1) Rank	(2) Most Abundant Forb (Dominance Type)		(3) Dom. Type Code	(4) Map Unit Code	(5) Map Group
1	<i>Dodecatheon redolens</i>	scented shootingstar	DORE	RV	R
2	<i>Primula parryi</i>	Parry's primrose	PRPA	RV	R
3	<i>Veronica anagallis-aquatica</i>	water speedwell	VEAN2	RV	R
4	<i>Ivesia cryptocaulis</i>	Charleston Peak mousetail	IVCR	ALP	A
5	<i>Oxytropis oreophila</i>	mountain oxytrope	OXOR2	ALP	A
6	<i>Artemisia dracunculus</i>	tarragon	ARDR4	ALP	A
7	<i>Artemisia michauxiana</i>	Michaux's wormwood	ARMI4	UHE	H
8	<i>Cirsium clokeyi</i>	whitespine thistle	CICL2	UHE	H
9	<i>Sphaeralcea ambigua</i>	desert globemallow	SPAM2	UHE	H
10	<i>Bailleya multiradiata</i>	desert marigold	BAMU	UHE	H
11	<i>Solidago spectabilis</i>	Nevada goldenrod	SOSP3	UHE	H
12	<i>Heuchera rubescens</i>	pink alumroot	HERU	UHE	H
13	<i>Lomatium ravenii</i>	Lassen parsley	LORA	UHE	H
14	<i>Melilotus officinalis</i>	sweetclover	MEOF	AHE	H
15	<i>Salsola tragus</i>	prickly Russian thistle	SATR12	AHE	H
	Species not listed above		See Instruction 3 above		
	Species unidentifiable		UNKNOWN		

Key to Non-Vegetated Land Cover and Land Use Types

		<u>Map Group</u>
1a. Area is currently developed for urban, residential, administrative use	Developed (DEV)	N
1b. Area is not currently developed for urban, residential, administrative use	2	
2a. Area is dominated by open water or a confined water course	Water (WA)	N
2b. Area is not dominated by open water or a confined water course	3	
3a. Area is dominated by barren land (e.g., bare ground, bedrock, scree/talus) or sparse vegetation	Barren/Rock/Sparse Veg (BR/SV)	N
3b. Area not as above.	Undefined (UND)	

Appendix A. Absolute and Relative Cover

Absolute cover of a plant species is the proportion of a plot's area included in the perpendicular downward projection of the species. These are the values recorded when sampling a vegetation plot. Relative cover of a species is the proportion it composes of the total plant cover on the plot (or the proportion of a layer's cover). Relative cover values must be calculated from absolute cover values. For example, we estimate overstory canopy cover on a plot as follows: ponderosa pine 42%, white fir 21%, and aspen 7%. These values are the absolute cover of each species. The relative cover of each species is calculated by dividing each absolute cover value by their total (70%) as follows:

	Absolute Cover	Calculation	Relative Cover
Ponderosa pine	42%	$100 \times 42 / 70 =$	60%
White fir	21%	$100 \times 21 / 70 =$	30%
Aspen	7%	$100 \times 7 / 70 =$	10%
Total of values	70%		100%

We calculate relative cover of 60% for ponderosa pine. This means that ponderosa pine makes up 60% of the overstory tree canopy cover on the plot. Relative cover always adds up to 100%, but absolute cover does not. Because plant canopies can overlap each other, absolute cover values can add up to more than 100%. In our example, the total of the absolute cover values is 70, but this does not mean that overstory trees cover 70% of the plot. Overstory tree cover would be 70% if there were no overlap among the crowns of the three species, but only 42% with maximum overlap. The actual overstory cover must be determined when sampling the plot if the information is desired, but the sum of the species cover values is used to calculate relative cover.

If the absolute cover values in our example were all halved or all doubled, the relative cover of each species would not change even though overstory tree cover would be very different. Halving the absolute values would mean overstory cover would be between 21 and 35%, depending on the amount of overlap. Doubling the values would mean overstory cover could range from 84 to 100% (not 140%). Each of these scenarios would be very different from the original example in terms of wildlife habitat value, fuel conditions, fire behavior, and silvicultural options; but the relative cover of the tree species would be exactly the same. We should also note that they also could vary widely in spectral signature. The key point here is that relative cover values by themselves provide limited ecological information and may be of little value to resource managers. Relative cover can be derived from absolute cover, but absolute cover cannot be derived from relative cover values. This is why absolute cover is recorded in the field.

Appendix B. Map Group and Map Unit Codes

Map Group	Code
Alpine	A
Riparian	R
Herbland	H
Shrubland	S
Conifer Forest	C
Deciduous Forest	D
Woodland	W
Non-Vegetated/Sparse Vegetation	N

Vegetation Map Unit	Code
Alpine	A
Alpine Vegetation	ALP
Riparian	R
Riparian Vegetation	RV
Herbland	H
Annual Herbaceous	AHE
Upland Herbaceous	UHE
Shrubland	S
Blackbrush Shrubland	BBSH
Mojave Shrubland	MOSH
Mountain Shrubland	MS
Rock Outcrop Shrubland	ROSH
Conifer Forest	C
Bristlecone Pine	BCP
Bristlecone Pine/Limber Pine	BC/LM
Ponderosa Pine	PP
White Fir/Ponderosa Pine	WF/PP
Deciduous Forest	D
Aspen	AS
Woodland	W
Gambel Oak	GO
Mountain Mahogany Mix	MMmix
Pinyon-Juniper/Desert Shrub	PJ/DE
Pinyon-Juniper/Montane Shrub	PJ/MT
Non-Vegetated/Sparse Vegetation	N
Developed	DEV
Barren/Sparse Vegetation	BR/SV
Water	WA

Appendix IV: Field Reference Data Collection Guide and Protocols

Field Reference Data Collection Guide & Protocols Spring Mountains National Recreation Area 2013 RSAC Field Data Collection Protocol

Introduction:

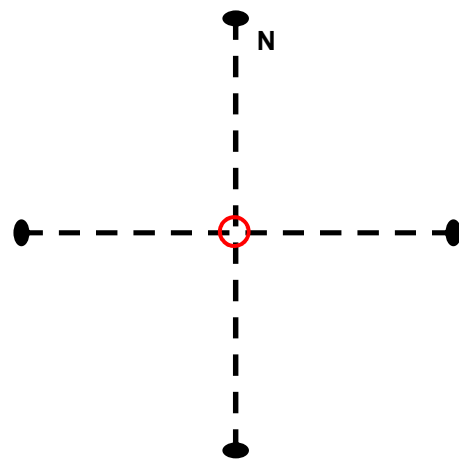
RSAC will collect field data for the SMNRA existing vegetation mapping project. This data, along with the information collected by Dr. Charlet and Dave Tart, will be used to develop the models for producing the vegetation maps. The goal of this activity is to gather opportunistic vegetation communities in homogenous polygons.

Methods:

Sites will be selected in the field using laptop computers and handheld GPS tablets. Homogenous map features (segments) with relatively uniform vegetation characteristics will be visited and dominance type, vegetation type, vegetation group, canopy cover, and size class will be assigned using the established SMNRA vegetation key and similar protocols that were used for data collection on other Region 4 mid-level existing vegetation mapping projects.

A single observation will be made for each field site based on a segment-wide assessment instead of using multiple plots to determine the predominant vegetation characteristics. Ocular estimates will be made to assign map unit attributes.

For a portion of the shrubland plots (calibration plots), canopy cover will be optionally measured using line intercept transects. The intercept method involves laying out two perpendicular 100-foot transects through the plot center; one running north-south and one running east-west, using tapes and stakes. Do not allow the vegetation to deflect the alignment of the tape. Estimate and record the number of feet of live canopy cover intercepted for each species within each 10-foot transect increment. Round the estimate to the nearest 0.5 foot for each 10-foot increment. Gaps within a single plant, flowers, and flower stalks should be counted as part of the shrub. The total for each transect is the canopy percentage. The N/S



transect and E/W transect percentages are then averaged to calculate the overall shrub canopy cover.

An adaptive sampling strategy will be used in which the total numbers of each vegetation type are tabulated as sites are being collected. This will help to help identify potentially underrepresented classes. The majority of new field data will be collected within ¼ mile of roadsides in order to expedite the sampling effort. RedCastle personnel will use this added flexibility to focus field efforts on project needs, gather good representative sites, and maximize sampling efficiency.

Diameter at Root Collar (DRC)

(Adapted from Interior West Forest Inventory and Analysis P2 Field Procedures, V5.00)

For species requiring diameter at the root collar, measure the diameter at the ground line or at the stem root collar, whichever is higher. For these trees, treat clumps of stems having a unified crown and common root stock as a single tree; examples include mesquite, juniper, and mountain mahogany. Treat stems of woodland species such as Gambel oak and bigtooth maple as individual trees if they originate below the ground.

Measuring woodland stem diameters: Before measuring DRC, remove the loose material on the ground (e.g., litter) but not mineral soil. Measure just above any swells present, and in a location so that the diameter measurements are a good representation of the volume in the stems (especially when trees are extremely deformed at the base). Stems must be at least 1 foot in length and at least 1.0 inch in diameter 1 foot up from the stem diameter measurement point to qualify for measurement. Whenever DRC is impossible or extremely difficult to measure with a diameter tape (e.g., due to thorns, extreme number of limbs), stems may be estimated and recorded to the nearest class. Additional instructions for DRC measurements are illustrated in Figures A and B.

Computing and Recording DRC: For all trees requiring DRC, with at least one stem 1 foot in length and at least 1.0 inch in diameter 1 foot up from the stem diameter measurement point, DRC is computed as the square root of the sum of the squared stem diameters. For a single-stemmed DRC tree, the computed DRC is equal to the single diameter measured.

Use the following formula to compute DRC:

$$\text{DRC} = \text{SQRT} [\text{SUM} (\text{stem diameter}^2)]$$

Round the result to the nearest 0.1 inch. For example, a multi-stemmed woodland tree with stems of 12.2, 13.2, 3.8, and 22.1 would be calculated as:

$$\begin{aligned}
 \text{DRC} &= \text{SQRT} (12.2^2 + 13.2^2 + 3.8^2 + 22.1^2) \\
 &= \text{SQRT} (825.93) \\
 &= 28.74 \\
 &= 28.7
 \end{aligned}$$

If a previously tallied woodland tree was completely burned and has re-sprouted at the base, treat the previously tallied tree as dead and the new sprouts (1.0-inch DRC and larger) as part of a new tree.

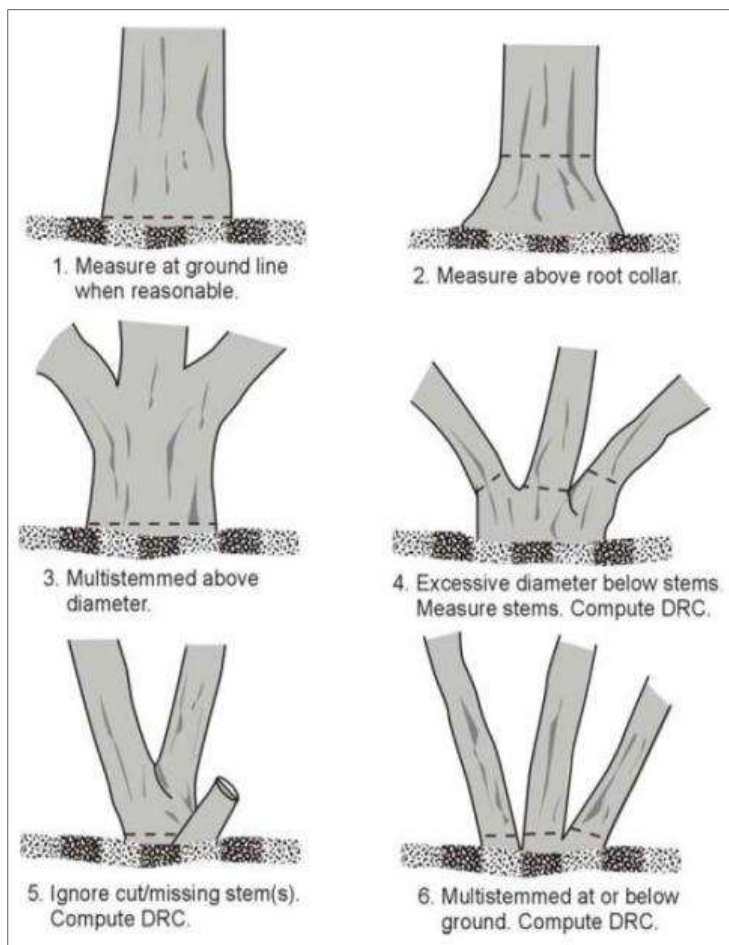


Figure A. How to measure DRC in a variety of situations. The cut stem in example number 5 is < 1 foot in length.

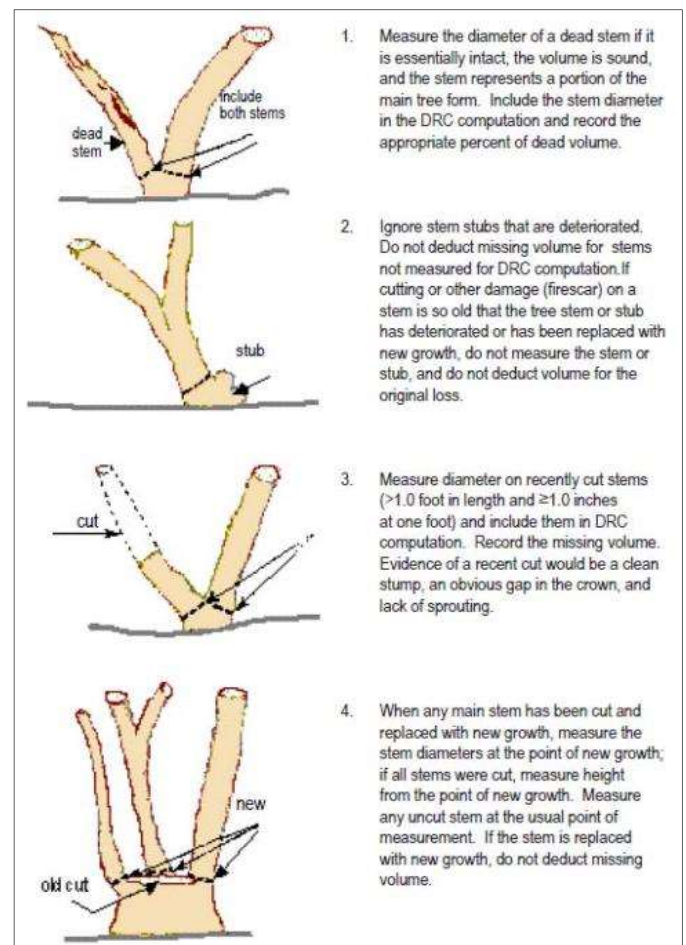


Figure B. Additional examples of how to measure DRC.

Vegetation, Vegetation Type, Canopy Cover Class, and Tree Size Class Codes:

Vegetation Group	Code
Deciduous Forest	D
Conifer Forest	C
Woodland	W
Shrubland	S
Herbland	H
Alpine	A
Riparian	R
Non-Vegetated/Sparse Vegetation	N

Vegetation Type	Code
Aspen	AS
Ponderosa Pine	PP
White Fir/Ponderosa Pine	WF/PP
Bristlecone Pine/Limber Pine	BC/LM
Bristlecone Pine	BCP
Pinyon-Juniper/Desert Shrub	PJ/DE
Pinyon-Juniper/Montane Shrub	PJ/MT
Mountain Mahogany Mix	MMmix
Gambel Oak	GO
Mojave Shrubland	MOSH
Blackbrush Shrubland	BBSH
Rock Outcrop Shrubland	ROSH
Mountain Shrubland	MS
Alpine Vegetation	ALP
Annual Herbaceous	AHE
Upland Herbaceous	UHE
Riparian Vegetation	RV
Barren/Sparse Vegetation	BR/SV
Developed	DEV
Water	WA

Tree Canopy Cover Class	Code
10 – 20%	TC1
21 – 40%	TC2
41 – 70%	TC3
≥ 71%	TC4

Shrub Canopy Cover Class	Code
10 – 20%	SC1
21 – 30%	SC2
<u>≥</u> 31%	SC3

Tree Size Class	Code
Forest 0 – 8.9" DBH	FTS1
Forest 9 – 20.9" DBH	FTS2
Forest <u>≥</u> 21" DBH	FTS3
Woodland 0 – 11.9" DRC	WTS1
Woodland 12 – 17.9" DRC	WTS2
Woodland <u>≥</u> 18" DRC	WTS3

SMNRA NF – 2013 RSAC Quick Plot Field Data Form

Collector(s): _____ **M/D/YY:** _____ - _____ - _____

Plot ID: _____ Plot Type _____
X-Coord: _____ Y-Coord: _____
Photo #: _____ Dom Type 1 _____
Dom Type 2: _____ Dom Type Confd: _____
Veg Group: _____ Veg Type: _____
Canopy Cover: _____ Tree Size: _____
Notes: _____

Plot ID: _____ Plot Type _____
X-Coord: _____ Y-Coord: _____
Photo #: _____ Dom Type 1: _____
Dom Type 2: _____ Dom Type Confd: _____
Veg Group: _____ Veg Type: _____
Canopy Cover: _____ Tree Size: _____
Notes: _____

Plot ID: _____ Plot Type _____
X-Coord: _____ Y-Coord: _____
Photo #: _____ Dom Type 1 _____
Dom Type 2: _____ Dom Type Confd: _____
Veg Group: _____ Veg Type: _____
Canopy Cover: _____ Tree Size: _____
Notes: _____

Plot ID: _____ Plot Type _____
X-Coord: _____ Y-Coord: _____
Photo #: _____ Dom Type 1: _____
Dom Type 2: _____ Dom Type Confd: _____
Veg Group: _____ Veg Type: _____
Canopy Cover: _____ Tree Size: _____
Notes: _____

Plot ID: _____ Plot Type _____
X-Coord: _____ Y-Coord: _____
Photo #: _____ Dom Type 1 _____
Dom Type 2: _____ Dom Type Confd: _____
Veg Group: _____ Veg Type: _____
Canopy Cover: _____ Tree Size: _____
Notes: _____

Plot ID: _____ Plot Type _____
X-Coord: _____ Y-Coord: _____
Photo #: _____ Dom Type 1: _____
Dom Type 2: _____ Dom Type Confd: _____
Veg Group: _____ Veg Type: _____
Canopy Cover: _____ Tree Size: _____
Notes: _____

Plot ID: _____ Plot Type _____
X-Coord: _____ Y-Coord: _____
Photo #: _____ Dom Type 1 _____
Dom Type 2: _____ Dom Type Confd: _____
Veg Group: _____ Veg Type: _____
Canopy Cover: _____ Tree Size: _____
Notes: _____

Plot ID: _____ Plot Type _____
X-Coord: _____ Y-Coord: _____
Photo #: _____ Dom Type 1: _____
Dom Type 2: _____ Dom Type Confd: _____
Veg Group: _____ Veg Type: _____
Canopy Cover: _____ Tree Size: _____
Notes: _____

SMNRA NF – 2013 RSAC Calibration Plot Field Form

6- Access: _____

1- Reference Site ID#: _____ 2- Names: _____ 3- M/D/YY: _____

4- X-Coord: _____ Y-Coord: _____ 5- Field Photograph: _____

7 - Ocular Plot Composition

Tree	Cover	Shrub	Cover	Herbaceous	Cover	Non-Veg Cover	
Others Combined		Others Combined		Other Grasses Combined			
				Other Forbs Combined			
Total		Total		Total		Total	

Lifeform & Non-Veg totals must add up to 100%.

8 - Tree Cover by DBH or DRC Diameter Class

Tree Code	Cover	FTS1 0 - 8.9"	FTS2 9 - 20.9"	FTS3 ≥ 21"	WTS1 0 - 11.9"	WTS1 12 - 17.9"	WTS2 ≥ 18"
Others Combined							
Total							

9 - Shrub Canopy Cover – by line intercept

Transect North/South

Plant Code	0-10'	10-20'	20-30'	30-40'	40-50'	50-60'	60-70'	70-80'	80-90'	90-100'	Total

Transect East/West

Total N/S Shrub CC

Plant Code	0-10'	10-20'	20-30'	30-40'	40-50'	50-60'	60-70'	70-80'	80-90'	90-100'	Total
								Total E/W Shrub CC			
								Overall Shrub CC			

10- Dominance Type: _____ 11- Veg Type: _____ 12- Veg Group: _____

13- Canopy Cover: _____ 14- Tree Size: _____

15- Notes:

Appendix V: eCognition Layer Weights

Layer weights used to develop the modeling units (segments) in eCognition software

Layer	Weight
Landsat 8 PC1	1.6
Landsat 8 PC2	1.6
Landsat 8 PC3	1.6
Slope-Aspect Transformation (Cos)	0.8
Slope-Aspect Transformation (Sin)	0.8
WorldView-2 Blue	0.6
WorldView-2 Green	0.6
WorldView-2 Red	0.6
WorldView-2 PC1	1
WorldView-2 PC2	1
WorldView-2 PC3	1

Appendix VI: Tree Size Class Modeling Data Layers

Data layers used in the modeling of tree size for the SMNRA

Data Source	# of Layers	Spatial Resolution	Description	Statistics Used	Total # of Predictors
Landsat 5 - September	7	30m	NDVI, Tasseled Cap and Principal Components	Mean and Standard Deviation	14
Landsat 8 - April	7	30m	NDVI, Tasseled Cap and Principal Components	Mean and Standard Deviation	14
Landsat 8 – May	7	30m	NDVI, Tasseled Cap and Principal Components	Mean and Standard Deviation	14
Landsat 8 - June	7	30m	NDVI, Tasseled Cap and Principal Components	Mean and Standard Deviation	14
Landsat - Time series NBR	5	30m	Normalized burn ratio: 25 th percentile difference, 50 th percentile difference, 75 th percentile difference, max and min	Mean, Medium, and Standard Deviation	15
Landsat - Time series NDVI	5	30m	NDVI: 25 th percentile difference, 50 th percentile difference, 75 th percentile difference, max and min	Mean, Medium, and Standard Deviation	15
Landsat - Time series Z-Score	5	30m	Forest Z-Score: 25 th percentile difference, 50 th percentile difference, 75 th percentile difference, max and min	Mean, Medium, and Standard Deviation	15
WorldView-2	9	1.8m	Red, blue, green, NIR, red edge, coastal, yellow, near-IR2 and NDVI	Mean and Standard Deviation	18
DEM	7	10m	Elevation, slope, aspect, heatload, slope position and surface/ground ratio	Mean and Standard Deviation	14
ifSAR	1	5m	Delta change product (to detect canopy height)	Mean and Standard Deviation	2
Soils - SURGO	2	10m	Available water storage and soil organic carbon stock estimate	Majority	2

Appendix VII: Draft Map Review

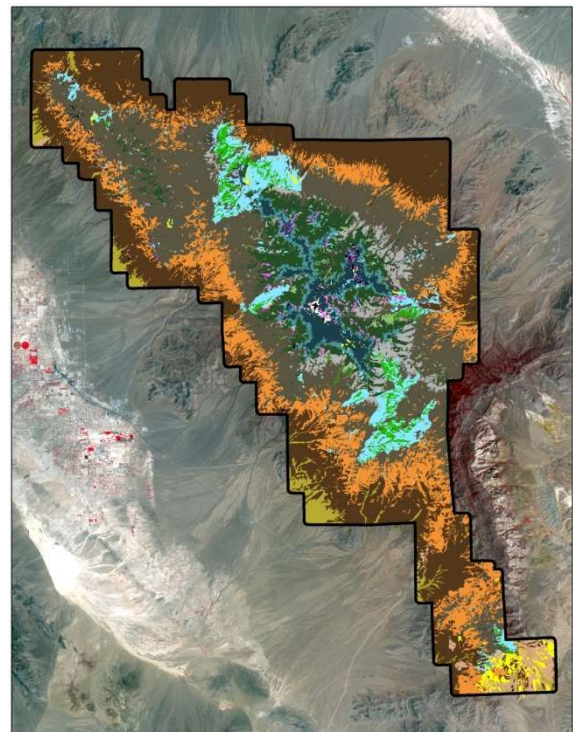
EXISTING VEGETATION MAPPING DRAFT REVIEW SPRING MOUNTAINS NRA EXISTING VEGETATION MAPPING - DRAFT MAP REVIEW August 29th 2013

Background:

The Remote Sensing Applications Center (RSAC) was tasked by the Spring Mountains NRA and Intermountain Region to develop a set of mid-level existing vegetation maps. Existing vegetation is the plant cover, or floristic composition and vegetation structure, occurring at a given location at the current time (Brohman and Bryant 2005). This should not be confused with Potential Natural Vegetation (PNV) which describes the vegetation communities that would be established if all successional sequences were completed without interference by man under the present climatic and edaphic conditions (Tuxen 1956). The final map products for this project will include existing vegetation type, canopy cover, and tree size class.

The project has utilized remote sensing techniques and field data to map existing vegetation types. During this process, RSAC has worked with the NRA and the Regional Office to collect and develop the data layers required for implementing semi-automated remote sensing techniques. WorldView-2 satellite imagery collected in May, 2013 and digital elevation models were used to create “mapping segments” (GIS polygons) from a combination of spectral information and physical characteristics of the landscape. These segments were then assigned a vegetation type using an ensemble classifier. The current minimum mapping unit (smallest polygon size) is 1 acre. The final maps will be produced at a 1:100,000 scale.

This review will focus on the draft vegetation type map only. The meeting scheduled at the SMNRA Office in Las Vegas is planned to solicit feedback from knowledgeable staff members who can evaluate the draft maps and help improve the depiction of existing vegetation on the final maps. Map revisions will be based almost entirely on the information provided from the



review process. Digital maps are available via Webmap. Hardcopy maps have also been produced at a scale of roughly 1:65,000.

Vegetation type map units:

The vegetation type map units were determined prior to the 2013 field season through a collaborative effort between the cooperating parties (SMNRA, RO and RSAC). Changes were made in accordance with information gained throughout the field season and early mapping efforts. A list of the resultant vegetation type map units and acres forest-wide and of each type in each district are on the following pages.

Vegetation Type Map Unit	Acres	Percent of Total
Mojave Shrubland	6,199.7	1.9%
Blackbrush Shrubland	76,134.7	23.7%
Montane Shrubland	18,611.2	5.8%
Rock Outcrop Shrubland	1,901.2	0.6%
Riparian Shrubland	230.5	0.1%
Riparian Herbland	19.2	0.0%
Gambel's Oak	6,508.8	2.0%
Pinyon-Juniper / Desert Shrub	52,003.4	16.2%
Pinyon-Juniper / Montane Shrub	96,584.1	30.0%
Mountain Mahogany / Singleleaf Pinyon	10,404.6	3.2%
Ponderosa Pine	1,845.8	0.6%
White Fir / Ponderosa Pine	25,812.7	8.0%
Bristlecone Pine / Limber Pine	7,252.8	2.3%
Bristlecone Pine	9,514.1	3.0%
Annual Herbland	3,716.6	1.2%
Upland Herbland	2,900.7	0.9%
Alpine Herbland	431.2	0.1%
Barren / Rock	851.3	0.3%
Developed	956.5	0.3%
Water	7.0	0.0%
	321,886.0	100.0%

Review Process:

For the review, provide as much information about the draft map as possible. You have been provided with digital and hardcopy draft maps. Either form of review is acceptable. Overall, it is important to focus your attention on the general vegetation patterns and distribution of vegetation types. We need information on what is correct and what is incorrect. Please remember this is a mid-level map (1:100,000 scale) and not a site map. This is not project level mapping; fine scaled vegetation patches or stands will not be represented on the final map.

For either the hard copy or digital map review you must follow the “Spring Mountains NRA Vegetation Keys” when determining the vegetation type map unit. This ensures that everyone is assigning types based on the same rules and descriptions.

In general, the draft map review process includes the following phases:

- Review the vegetation type proportion summaries provided in this procedure.
- Review the entire NRA. Focus on general vegetation distribution and patterns and determine if the overall community types that you see are represented.
- Next focus on specific areas that you are most familiar with. These include areas that you have done more detailed project work on or localized studies.
- If necessary follow up with field visits to areas that are confused and correct labels cannot be easily determined.

The next sections provide a description of reviewing both hardcopy and digital maps.

Hardcopy paper draft map review procedures:

Write notes, circle areas of concern, and document any other information on the hardcopy maps and fill in the review form provided. Label each area marked on the map with a unique ID comprised of your initials and then the edit number (e.g., MC-1, MC-2, and so on). Make sure the unique ID corresponds to the comments entered on the form. It is also important to include your name and contact information on the form to allow the mapping specialists to follow up with any questions and/or further discussion. A digital version of the form as Word document is also provided.

Digital draft map review procedures:

Digital versions of the draft map are available through webmap. It is important to review the general distribution and extent of vegetation patterns at a scale that corresponds to the

midlevel mapping scale, e.g., 1:50,000 to 1:100,000. To access the map layers using webmap use the following directions.

Webmap instructions:

Open webmap. Go to: http://166.2.126.153/vegmaps/Spring_Mountains_NRA

1. **The interface.** A web browser will open, click on the OK button and the map will be displayed automatically. There are five buttons at the top of the screen, just to the right of center. These buttons from left to right are: **Layer List**, **Legend**, **Identify**, **Swipe Spotlight**, **Edit**, and **Print**.
 - a. The **Layer List** allows you to turn on or off the Draft Map and/or the Edits polygons
 1. To change the **Transparency** of either of the two layers, you can click the down-arrow next to the layer in the list and select **Transparency**. Clicking and dragging along the bar allows you to change from 0% transparent to 100%.
 - b. The **Legend** can be activated and deactivated by clicking on legend icon. It is recommended to resize the legend so that all veg types can be seen simultaneously if your screen resolution allows.
 - c. The **Identify** button allows you to click anywhere on the VT map and identify the vegetation map unit being displayed.
 - d. The **Swipe Spotlight** allows you to either **Swipe** the map in any of the four cardinal directions to reveal the underlying imagery or utilize the **Spotlight** to see directly through the map via a circle of a defined radius.
 1. Make sure you select the **Active Layer** first, and then select either the **Swipe** or the **Spotlight**. Occasionally, you will have to click it twice.
 - e. The **Edit** button allows you to draw in polygons representing desired changes to the map. Again, it is recommended that you re-size the window so you can see all of the editable map units.
 - f. The **Print** button allows you to print your current viewing extent.

Navigation tools (**zoom**, **pan**, etc.) can be found on the upper-left hand portion of the screen

You can also change the backdrop by clicking the **Basemap** options in the top right portion of the screen. Here, you can change from imagery to street maps, terrain maps, etc.

2. **Making edits to the map.** This is where you will draw polygons representing areas on the map you believe to be misclassified or needing improvement in a particular way. To begin making edits, click on the **Edit** button at the top of the screen. Select the map unit class from the list that you wish to place on the map

(what you want to edit the map to). Begin drawing a polygon around the area of concern by placing individual vertices. **Be deliberate and do not rush your vertex placement** – the webmap service will not register vertices placed too rapidly. Double click to complete the polygon. A window will pop up that allows you to either **Delete** the polygon or **Attribute** the polygon with your name (or initials) and your **Comments**.

There are a number of tools at the bottom of the **Edit** window that allow you to manipulate polygons that are already drawn. The **Eraser** allows you to clear your selection. The **X** allows you to delete your selected feature. The **Create Options** drop down list allows you to select the type of polygon to edit (i.e. **Freehand**, **Point-to-Point**, **Circle**, etc.). The **Scissors** allows you to cut polygons into multiple parts based on placed vertices. The **Split Polygons** tool allows you to split the polygon in two. The **Reshape Polygons** tool allows you to reshape your polygons. The **Undo** and **Redo** tools allow you to undo and redo any edits you make.

All edits made will save automatically when you close your webmap session.

Google Earth instructions:

A KML map of the Sawtooth Draft Vegetation map has been created for users who are more comfortable viewing the map in Google Earth. The KML file is stored on the T drive and can be run from the T drive but it is not recommended due to the file size of the KML. Instructions for copying the KML to a local computer (or network drive) and then running the KML are listed below.

1. Copy this entire folder from the T drive:
“T:\FS\NFS\R04\Collaboration\VCMQ\HumboldtToiyabe\GIS\VegMapping\SMNRA\SMNRA_KML”.
2. Paste onto your own computer or a network drive that works faster than the T drive.
3. Go into the SMNRA_KML folder (that is now on your computer)
4. Double-click the “SMNRA_Draft_VTmap.kmz” file.
5. The file will now open in Google Earth.

SMNRA DMR Questions & Observations:

This section provides specific questions and observations about the vegetation map throughout the NRA.

- Pinyon-Juniper / Montane Shrub almost doubles the acreage of Pinyon-Juniper / Desert Shrub. Could it be over-mapped?

- Quite a bit of area in the low-lying regions of the western portion of the NRA have been mapped as Mojave shrublands. Most of these areas are largely inaccessible by all but very-high clearance 4WD vehicles. Is it over-mapped in these areas?
- Is the peak of Mt. Charleston (area above tree-line) being represented accurately? Can alpine herblands be found all the way at the summit, or is it entirely barren? Entirely alpine?
- Are there alpine herbland areas other than Mummy Mtn and Charleston?
- Only ~1,800 ac of the NRA is mapped as Ponderosa Pine. Is Ponderosa Pine being under-mapped? (keep the Vegetation Keys in mind)
- The vast majority of Mountain Mahogany / Singleleaf Pinyon appears to have been mapped on the east and south slope of the range. Is this likely to be correct?
- There is an interesting mix of upland and annual herblands growing in the burn scar area on the southeastern slopes of Potosi. Do these distributions look accurate? Is upland herbland being overmapped?
- There are very few pockets of true conifer forest (WF/PP) in the Potosi area that we were able to find. As a result, very little was mapped. Is it being under-represented in this area?
- Pure bristlecone pine has been mapped as having quite a bit more acreage than bristlecone-limber pine mix. Does this seem accurate? Does the BC/LM elevation band seem too narrow?
- Is there bristlecone pine on top of Griffith Peak?
- Are the avalanche chutes coming off of Charleston, Devil's Thumb and Mummy Mountain mostly Aspen-dominated? Upland herblands? Alpine herblands? Montane shrublands?
- Are the slopes at the ski resort Upland herblands? – Right now they are mapped as a mix of Annual and Upland.
- Are most of the WUI treatments <10% tree cover?
- For the most part, the more recent and lower lying burn scars are being mapped as either Annual Herblands or Upland Herblands, whereas the higher elevation fires are typically being mapped as Montane Shrubland or Gambel's Oak. To your knowledge, are the regenerating vegetation types being represented correctly?

References:

Brohamn, R.; Bryant L. editors. 2005. Existing vegetation classification and mapping technical guide. Gen Tech. Rep. WO-67. Washington DC: U.S. Department of Agriculture, Forest Service, Ecosystem Management Coordination Staff. 305 p.

Tuxen, R. 1956. Die heutige naturliche potentielle Vegetation als Gegenstand der vegetationskartierung. Remagen. Berichtze zur Deutschen Landekunde. 19:200-246.

Appendix VIII: Merge Rules for Segments Less Than MMU Size

Merge Rule for Segments Less Than MMU Size Spring Mountains National Recreation Area Merge Rules for Segments less than MM Size

Vegetation Types:

- Aspen (AS)
- Ponderosa Pine (PP)
- White Fir/Ponderosa Pine (WF/PP)
- Bristlecone Pine /Limber Pine (BC/LM)
- Bristlecone Pine (BCP)
- Pinyon-Juniper/Desert Shrub (PJ/DE)
- Pinyon-Juniper/Montane Shrub (PJ/MT)
- Mountain Mahogany Mix (MMmix)
- Gambel Oak (GO)
- Mojave Shrubland (MOSH)
- Blackbrush Shrubland (BBSH)
- Rock Outcrop Shrubland (ROSH)
- Mountain Shrubland (MS)
- Alpine Vegetation (ALP)
- Annual Herbaceous (AHE)
- Upland Herbaceous (UHE)
- Riparian Vegetation (RV)
- Barren/Sparse Vegetation (BR/SV)
- Developed (DEV)
- Water (WA)

Filter Groups:

conifer	= PP, WF/PP, BC/LM, BCP
desertshrub	= MOSH, BBSH
mountainshrub	= MTSH, ROSH, GO
woodland	= PJ/DE, PJ/MT, MM/SP
herbaceous	= AHE, UHE, ALP
Developed	= DEV (no minimum size, no filtering)
Water	= WA (no minimum size, no filtering)

Filtering Rules: (5 acres except where otherwise noted)

Aspen (2 acre)

1. White Fir/Ponderosa Pine
2. Ponderosa Pine
3. Bristlecone Pine
4. Bristlecone Pine/Limber Pine
5. mountainshrub
6. herbaceous
7. Riparian Vegetation
8. Barren/Sparse Vegetation
9. Mountain Mahogany Mix
10. Pinyon-Juniper/Montane Shrub
11. Pinyon-Juniper/Desert Shrub
12. desertshrub

Ponderosa Pine

1. White Fir/Ponderosa Pine
2. Mountain Mahogany Mix
3. Pinyon-Juniper/Montane Shrub
4. Bristlecone Pine/Limber Pine
5. Aspen
6. Pinyon-Juniper/Desert Shrub
7. Gambel Oak
8. Bristlecone Pine
9. mountainshrub
10. Riparian Vegetation
11. herbaceous
12. desertshrub
13. Barren/Sparse Vegetation

White Fir/Ponderosa Pine

1. Ponderosa Pine
2. Bristlecone Pine / Limber Pine
3. Aspen
4. Mountain Mahogany Mix
5. Pinyon-Juniper/Montane Shrub
6. Pinyon-Juniper/Desert Shrub
7. Gambel Oak
8. mountainshrub
9. Bristlecone Pine
10. Riparian Vegetation
11. herbaceous
12. desertshrub
13. Barren/Sparse Vegetation

Bristlecone Pine/Limber Pine

1. Bristlecone Pine
2. White Fir/Ponderosa Pine
3. Ponderosa Pine
4. Aspen
5. Mountain Mahogany Mix
6. Pinyon-Juniper/Montane Shrub
7. Pinyon-Juniper/Desert Shrub
8. Gambel Oak
9. mountainshrub
10. Riparian Vegetation
11. herbaceous
12. desertshrub
13. Barren/Sparse Vegetation

Mojave Shrubland

1. Blackbrush Shrubland
2. Annual Herbaceous
3. Barren/Sparse Vegetation
4. Rock Outcrop Shrubland
5. Mountain Shrubland
6. Pinyon-Juniper/Desert Shrub
7. Upland Herbaceous
8. Riparian Vegetation
9. Pinyon-Juniper/ Montane Shrub
10. Mountain Mahogany Mix
11. Gambel Oak
12. conifer
13. Aspen
14. Alpine Vegetation

Bristlecone Pine

1. Bristlecone Pine/Limber Pine
2. Alpine
3. White Fir/Ponderosa Pine
4. Ponderosa Pine
5. Aspen
6. Upland Herbaceous
7. Mountain Mahogany Mix
8. Pinyon-Juniper/Montane Shrub
9. Pinyon-Juniper/Desert Shrub
10. Gambel Oak
11. mountainshrub
12. Riparian Vegetation
13. Annual Herbaceous
14. Desertshrub
15. Barren/Sparse Vegetation

Blackbrush Shrubland

1. Mojave Shrubland
2. Annual Herbaceous
3. Rock Outcrop Shrubland
4. Pinyon-Juniper/Desert Shrub
5. Mountain Shrubland
6. Pinyon-Juniper/ Montane Shrub
7. Barren/Sparse Vegetation
8. Upland Herbaceous
9. Mountain Mahogany Mix
10. Gambel Oak
11. Riparian Vegetation
12. conifer
13. Aspen
14. Alpine vegetation

Mountain Shrubland

1. Gambel Oak
2. Pinyon-Juniper/ Montane Shrub
3. Blackbrush Shrubland
4. Rock Outcrop Shrub
5. Mountain Mahogany Mix
6. Pinyon-Juniper/Desert Shrub
7. Aspen
8. conifer
9. Upland Herbaceous
10. Annual Herbaceous
11. Mojave Shrubland
12. Riparian Vegetation
13. Barren/Sparse Vegetation
14. Alpine Vegetation

Riparian Vegetation (1 acre)

1. herbaceous
2. mountainshrub
3. conifer
4. Aspen
5. Desertshrub
6. woodland
7. Barren/Sparse Vegetation

Gambel Oak

1. Mountain Shrubland
2. Pinyon-Juniper/Montane Shrub
3. Mountain Mahogany Mix
4. conifer
5. Aspen
6. Rock Outcrop Shrub
7. Blackbrush Shrubland
8. Pinyon-Juniper/Desert Shrub
9. Mojave Shrubland
10. Riparian Vegetation
11. Herbaceous
12. Barren/Sparse Vegetation

Rock Outcrop Shrubland (2 acre)

1. Barren/Sparse Vegetation
2. Mountain Shrubland
3. Gambel Oak
4. herbaceous
5. desertshrub
6. woodland
7. Aspen
8. Conifer
9. Riparian Vegetation

Pinyon-Juniper/Desert Shrub

1. Pinyon-Juniper/Montane Shrub
2. Mountain Mahogany Mix
3. Blackbrush Shrubland
4. Mojave Shrubland
5. Mountainshrub
6. conifer
7. Aspen
8. herbaceous
9. Barren/Sparse Vegetation
10. Riparian Vegetation

Pinyon-Juniper/Montane Shrub

1. Pinyon-Juniper/Desert Shrub
2. Mountain Mahogany Mix
3. mountainshrub
4. conifer
5. Blackbrush Shrubland
6. Mojave Shrubland
7. herbaceous
8. Aspen
9. Barren/Sparse Vegetation
10. Riparian Vegetation

Annual Herbaceous

1. Upland Herbaceous
2. Barren/Sparse Vegetation
3. Mountainshrub
4. desertshrub
5. Alpine Herbaceous
6. Riparian Vegetation
7. woodland
8. conifer
9. Aspen

Upland Herbaceous

1. Alpine Herbaceous
2. Barren/Sparse Vegetation
3. mountainshrub
4. conifer
5. Aspen
6. Annual Herbaceous
7. woodland
8. desertshrub
9. Riparian

Mountain Mahogany/Singleleaf Pinyon

1. Pinyon-Juniper/Montane Shrub
2. conifer
3. mountainshrub
4. Pinyon-Juniper/Desert Shrub
5. Blackbrush Shrubland
6. Mojave Shrubland
7. herbaceous
8. Aspen
9. Barren/Sparse Vegetation
10. Riparian Vegetation

Alpine Vegetation (2 acre)

1. Upland Herbaceous
2. Barren/Sparse Vegetation
3. conifer
4. Aspen
5. mountainshrub
6. Annual Herbaceous
7. Riparian
8. woodland
9. desertshrub

Barren/Sparse Vegetation (2 acre)

1. Alpine Herbaceous
2. Upland Herbaceous
3. Annual Herbaceous
4. mountainshrub
5. conifer
6. Aspen
7. woodland
8. desertshrub
9. Riparian Vegetation

Canopy Cover Classes

Filtering Rules: (5 acres except where otherwise noted)

- Tree canopy 1
- Tree canopy 2
- Tree canopy 3
- Tree canopy 4
- Aspen canopy 1
- Aspen canopy 2
- Aspen canopy 3
- Aspen canopy 4
- Shrub canopy 1
- Shrub canopy 2
- Shrub canopy 3
- Rock Outcrop Shrubland canopy 1
- Rock Outcrop Shrubland canopy 2
- Rock Outcrop Shrubland canopy 3
- Riparian Vegetation canopy 1
- Riparian Vegetation canopy 2
- Riparian Vegetation canopy 3

Tree canopy 1

- Tree canopy 2
- Tree canopy 3
- Tree canopy 4

Tree canopy 2

- Tree canopy 1
- Tree canopy 3
- Tree canopy 4

Aspen canopy 1 (2 acre)

- Aspen canopy 2
- Aspen canopy 3
- Aspen canopy 4

Aspen canopy 2 (2 acre)

- Aspen canopy 1
- Aspen canopy 3
- Aspen canopy 4

Shrub canopy 1

- Shrub canopy 2
- Shrub canopy 3

Shrub canopy 2

- Shrub canopy 1
- Shrub canopy 3

Tree canopy 3

- Tree canopy 2
- Tree canopy 4
- Tree canopy 1

Tree canopy 4

- Tree canopy 3
- Tree canopy 2
- Tree canopy 1

Aspen canopy 3 (2 acre)

- Aspen canopy 2
- Aspen canopy 4
- Aspen canopy 1

Aspen canopy 4 (2 acre)

- Aspen canopy 3
- Aspen canopy 2
- Aspen canopy 1

Shrub canopy 3

- Shrub canopy 2
- Shrub canopy 1

Rock Outcrop Shrub canopy 1 (2 acre)

- Rock Outcrop Shrub canopy 2
- Rock Outcrop Shrub canopy 3

Rock Outcrop Shrub canopy 2 (2 acre)

- Rock Outcrop Shrub canopy 1
- Rock Outcrop Shrub canopy 3

Rock Outcrop Shrub canopy 3 (2 acre)

- Rock Outcrop Shrub canopy 2
- Rock Outcrop Shrub canopy 1

Riparian Vegetation canopy 1 (1 acre)

- Riparian Vegetation canopy 2
- Riparian Vegetation canopy 3

Riparian Vegetation canopy 2 (1 acre)

- Riparian Vegetation canopy 1
- Riparian Vegetation canopy 3
-

Riparian Vegetation canopy 3 (1 acre)

- Riparian Vegetation canopy 2
- Riparian Vegetation canopy 1

Tree Size Classes

Filtering Rules: (5 acres except where otherwise noted)

- | | | |
|----------------------|---------------------|------------------------|
| • Forest tree size 1 | • Aspen tree size 1 | • Woodland tree size 1 |
| • Forest tree size 2 | • Aspen tree size 2 | • Woodland tree size 2 |
| • Forest tree size 3 | • Aspen tree size 3 | • Woodland tree size 3 |

Forest tree size 1

- Forest tree size 2
- Forest tree size 3

Aspen tree size 1 (2 acre)

- Aspen tree size 2
- Aspen tree size 3

Forest tree size 2

- Forest tree size 1
- Forest tree size 3

Aspen tree size 2 (2 acre)

- Aspen tree size 1
- Aspen tree size 3

Forest tree size 3

- Forest tree size 2
- Forest tree size 1

Aspen tree size 3 (2 acre)

- Aspen tree size 2
- Aspen tree size 1

Woodland tree size 1

- Woodland tree size 2
- Woodland tree size 3

Woodland tree size 2

- Woodland tree size 1
- Woodland tree size 3

Woodland tree size 3

- Woodland tree size 2
- Woodland tree size 1

Appendix IX: Diagram of FIA and SMNRA Intensified Plot

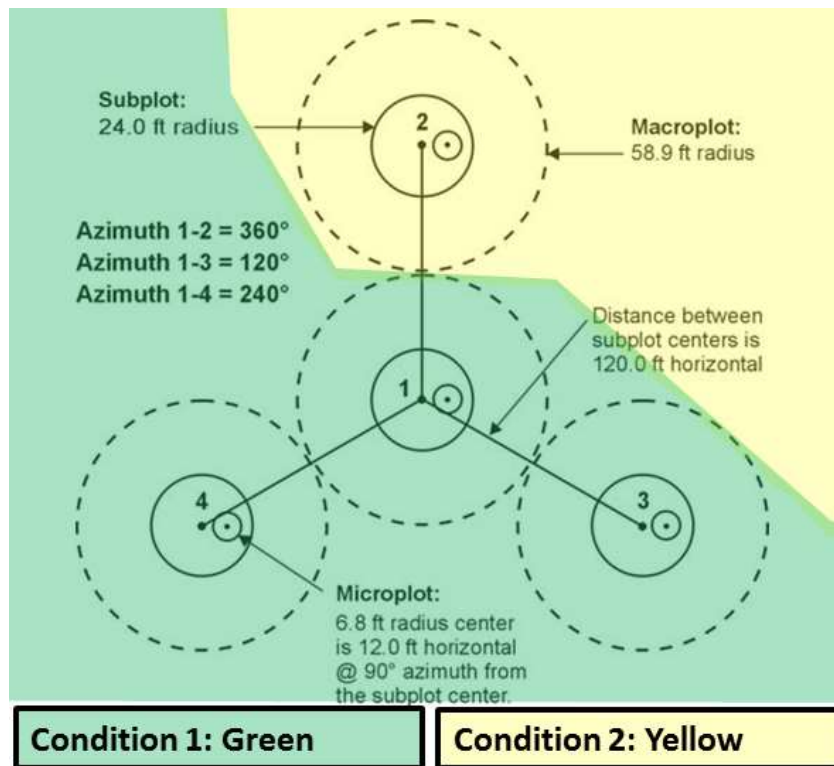


Figure 1: A schematic of an FIA plot showing the 4 subplots. In some cases, a condition change may occur on a plot, therefore giving multiple conditions to a single plot. The figure shows an example in which subplots 1, 3, and 4 have conditions 1. Subplot 2 has condition 2. Schematic source: USFS Forest Inventory and Analysis Program

Appendix X: Tree Canopy Cover Assessment

Tree Canopy Cover Assessment

Additional comparisons were made by the Remote Sensing Applications Center to address the following objectives: 1) evaluate agreement between the SMNRA map products and an independent photo-interpreted reference dataset from high-resolution imagery and 2) compare accuracy between the SMNRA canopy cover map and the freely available 2011 National Land Cover Database (NLCD) Tree Canopy Cover (TCC) dataset. Canopy cover maps were compared to reference photo-interpreted (PI) values in several ways to assess thematic map accuracy and also isolate accuracy from the effects of binning (grouping) canopy cover estimates according to the SMNRA canopy cover classes.

Methods

A random sample of 450 SMNRA modeling unit (segment) polygons was selected as reference sites in this accuracy assessment (Figure 1). Percent canopy cover was interpreted at the modeling unit (segment) polygon-level using high resolution aerial imagery. Multiple high resolution image datasets were used to interpret canopy cover including: 1-meter resolution color-infrared NAIP imagery from 2010 and 2013, 30 cm natural color imagery from 2011 (provided by Esri basemaps) and 1.8-m WorldView-2 imagery from spring 2013. Two analysts independently interpreted canopy cover. Differences in interpretation were resolved by taking the average of the two interpretations in cases where the differences were less than 10% absolute difference. Polygons with interpreted differences of 10% canopy cover or more were reinterpreted. These photo-interpreted canopy cover estimates were then used as the reference to assess the accuracy of the SMNRA canopy cover map products and the TCC data.

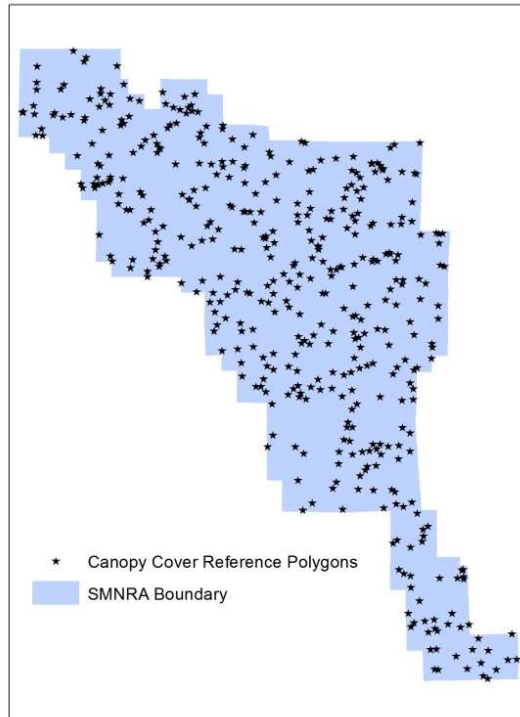


Figure 1: Locations of the 450 randomly selected modeling unit (segment) polygons that were used in the comparison of the SMNRA canopy cover map to photo-interpreted canopy cover and the 2011 NLCD-TCC map.

To provide a baseline for comparing and evaluating the SMNRA map products, the publically available 2011 NLCD TCC data was also compared to PI reference polygons. TCC is a nation-wide raster map product representing leaf-on percent tree canopy cover at a spatial resolution of 30 meters (<http://www.mrlc.gov/>). TCC pixel values were summarized at the polygon level and compared to the PI reference canopy cover estimates. The mean and median canopy cover pixel values were calculated for each sample polygon and compared to the photo-interpreted reference canopy cover values.

Errors between continuous map product values and reference values were calculated and used to estimate overall continuous map accuracy. This was accomplished with the continuous SMNRA canopy cover raster product that was used to create the final thematic tree canopy cover class map and the continuous mean and median values from the TCC data.

Accuracies of the corresponding thematic canopy cover class maps were estimated using confusion matrices. To do this, PI reference values were binned according to the SMNRA canopy cover classes (Table 1) and then compared to the corresponding map values. Overall accuracy was calculated using two methods, first using only the actual PI reference values and second, using fuzzy logic to account for variation in cover interpretation. In the fuzzy

assessment of overall accuracy, PI values that were misclassified but within 5% canopy cover of the next tree class were counted as correct.

Table 1. Summary of photo-interpreted canopy cover reference data classified according to the SMNRA canopy cover map classes and mapped classes in the different canopy cover classes.

	Canopy Cover Class (polygon count)				
Data Source	NF (<10%)	TC1 (10-20%)	TC2 (21-40%)	TC3 (41-70%)	TC4 (>71%)
PI Reference	189	107	115	32	2
SMNRA map	147	116	161	20	1
2011 NLCD-TCC (Classified)	182	100	153	10	0

Results

Direct comparison of continuous reference canopy cover estimates and the corresponding mapped values from the continuous SMNRA canopy cover map showed good agreement and a fairly good linear fit with an R^2 value of 0.63 (Figure 2). In contrast, the TCC data showed a lower level of agreement with an R^2 value of 0.37 (Figure 3). Both mean and median TCC values were evaluated; however, mean pixel value is reported here as it agreed better with reference data.

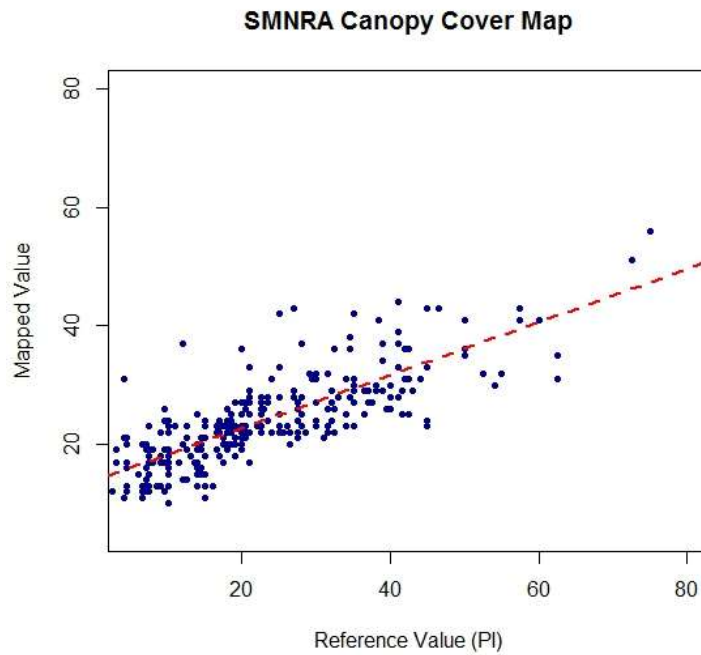


Figure 2: A scatterplot showing the linear fit ($R^2 = 0.63$) between the continuous canopy cover map used to develop the SMNRA canopy cover class map and the continuous photo-interpreted reference estimates.

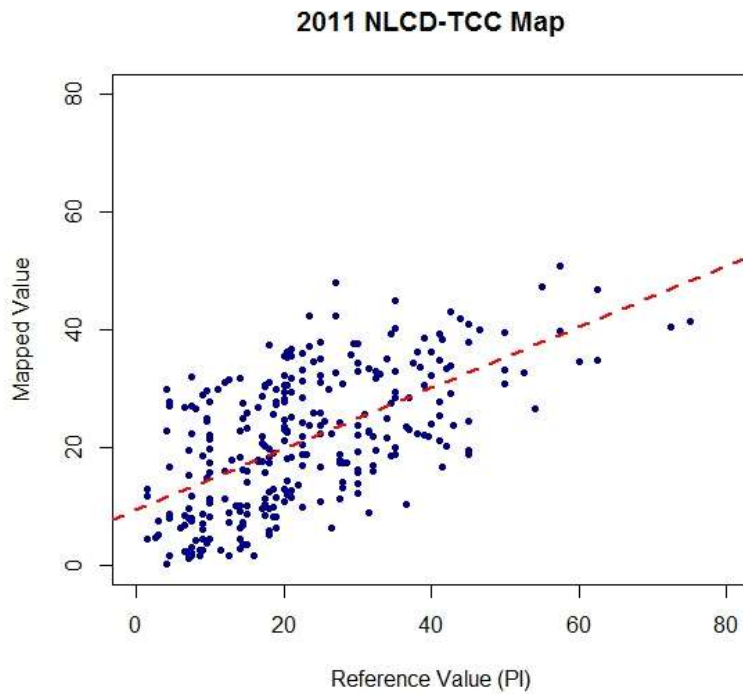


Figure 3: A scatterplot showing the linear fit ($R^2 = 0.37$) between the continuous canopy cover map used to develop the SMNRA canopy cover class map and the continuous 2011 NLCD-TCC average value for each polygon.

Evaluation of the SMNRA canopy cover map showed a relatively high overall thematic accuracy as calculated using both the original grouped reference values and the fuzzy reference values. Overall accuracies for the direct and fuzzy comparisons were 70 percent and 89 percent, respectively (Table 2). In contrast, overall agreement was lower between the TCC and reference data grouped using the same approach. In this case, overall accuracies for direct and fuzzy comparisons were 59 and 73 percent, respectively (Table 3). Producer's and user's percent accuracies were also higher in the SMNRA map than in TCC for all mapped classes.

Confusion in the SMNRA map tended to occur more frequently with adjacent classes. Because these classes are ordinal, this can be interpreted as an indicator that the SMNRA map agrees more closely with the reference data in this analysis. It should be noted that precision of the accuracy estimates are limited in TC4 (>70% canopy cover) as few observations were obtained in the sample dataset.

Table 2. Confusion matrix from the filtered SMNRA canopy cover map compared to the PI reference polygon canopy cover.

SMNRA map (filtered)	Reference (PI)						Producers'
	Canopy Class	NF	TC1	TC2	TC3	TC4	
	NF	141	5	1	0	0	147
	TC1	45	63	8	0	0	116
	TC2	3	38	98	22	0	161
	TC3	0	1	8	10	1	20
	TC4	0	0	0	0	1	1
Total		189	107	115	32	2	445
User's		75%	59%	85%	31%	50%	70%
Fuzzy Overall (within 5%)							89%

Table 3. Confusion matrix from the NLCD-TCC product averaged to the SMNRA polygons and compared to the PI reference canopy cover.

NLCD-TCC (2011 analytical product)	Reference (PI)						Producers'
	Canopy Class	NF	TC1	TC2	TC3	TC4	
	NF	149	30	3	0	0	182
	TC1	24	37	35	4	0	100
	TC2	16	40	73	23	1	153
	TC3	0	0	4	5	1	10
	TC4	0	0	0	0	0	0
Total		189	107	115	32	2	445
User's		79%	35%	63%	16%	0%	59%
Fuzzy Overall (within 5%)							73%